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May 13, 2019

Mr. Mark Purcell
Superfund Division (6SF)
U.S. Environmental Protection Agency - Region 6
1445 Ross Avenue, Suite 1200
Dallas, TX 75202

Re: Grants Reclamation Project
2019 Background Investigation Work Plan Final

Dear Mark,

As indicated during the May 7, 2019 call with EPA and NMED, Homestake is providing the Final 2019 Grants Reclamation Project Background Investigation Work Plan for your information.

If you have questions or comments, please contact me at (775) 397-7215 or dlattin@barrick.com.

Respectfully,

Daniel Lattin, P.E.
Project Evaluation Manager
Homestake Mining Company of California

Homestake Mining Company of California

WORK PLAN: 2019 BACKGROUND INVESTIGATION

Grants Reclamation Project Grants, New Mexico

May 13, 2019

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Grants Reclamation Project Grants, New Mexico

Prepared for:

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Prepared by:

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May 13, 2019

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ACRONYMS AND ABBREVIATIONS

%	percent
Arcadis	Arcadis U.S., Inc.
ASTM	ASTM International
bgs	below ground surface
CAP	Corrective Action Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
CSM	conceptual site model
EC	electrical conductivity
ERT	Electrical Resistivity Tomography
FRA	formal risk assessment
GPS	global positioning system
GRP	Grants Reclamation Project
GWPS	ground water protection standards
HASP	Site-Specific Health and Safety Plan
HMC	Homestake Mining Company of California
JSA	Job Safety Analysis

K	potassium
^{40}K	potassium-40
LTP	large tailing pile
MeV	million electron volts
mg/L	milligram per liter
NGR	natural gamma ray
NMED	New Mexico Environment Department
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
pCi/g	picocurie per gram
PPE	personal protective equipment
ppm	parts per million
PVC	polyvinyl chloride
QEMSCAN	Quantitative Evaluation of Materials by SCANning electron microscopy
RML	radioactive materials license
RO	reverse osmosis
SAP	Sampling and Analysis Plan
SBS	site-specific background standard
SDS	safety data sheet
SEM	scanning electron microscopy
SGR	spectral gamma ray
SMCB	San Mateo Creek Basin
SSE	Selective Sequential Extraction
STP	small tailing pile
TDS	total dissolved solids
Th	thorium
U	uranium
USEPA	United States Environmental Protection Agency
USGS	U.S. Geologic Survey

1. INTRODUCTION

The Homestake Mining Company of California (HMC) Grants Reclamation Project (GRP) is a former uranium mill located in the San Mateo Creek Basin in Cibola County, New Mexico, as shown on **Figure 1**. The mill operated from 1958 to 1990. Milling residue produced two on-site tailing piles: the small tailing pile (STP) and the large tailing pile (LTP), shown on **Figure 2**. Both tailing piles have influenced groundwater quality in the alluvial aquifer and shallow bedrock aquifer units immediately below and downgradient from the site. The site was placed on the United States Environmental Protection Agency's (USEPA's) Superfund National Priorities List (NPL) in September 1983 at the request of the State of New Mexico due to elevated selenium concentrations in the alluvial aquifer near the site. The Nuclear Regulatory Commission (NRC) administers a radioactive materials license (RML) held by the site (License No. SUA-1471); associated with this license are environmental restoration requirements that must be met prior to termination of the license. As a result of the NPL listing, the site's groundwater restoration activities are also being overseen under the USEPA's Superfund Program, in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (HMC 2012).

In 2016, the USEPA, with the assistance of the U.S. Geological Survey (USGS), initiated a reassessment of site background water quality standards at the GRP. Stakeholder groups have requested a better understanding of the site background standards and the occurrence of uranium in the alluvial system. Reassessment activities were conducted between June and October 2016 and included well reconnaissance, geophysics, and sampling of groundwater via micropurge, volume purge, and passive sampling techniques. HMC asked Arcadis U.S., Inc. (Arcadis) to collect split samples with the USGS during the 2016 sampling events.

Evaluation of the split sampling data has been ongoing; several meetings were held in 2018 with the USEPA, USGS, New Mexico Environment Department (NMED), and HMC regarding interpretations of the findings. The USEPA has sought additional information on the suitability of the monitoring well locations sampled in the alluvial aquifer upgradient from the site that were used to set site-specific background standards. Arcadis' interpretation of data collected during split sampling and during a subsequent soil investigation is that groundwater uranium concentrations in near-upgradient alluvial wells are attributed to naturally occurring uranium in soils. This interpretation is supported by data from the borehole installation adjacent to existing wells DD and DD2 (boreholes DD-BK and DD2-BK). Arcadis prepared a detailed report (Arcadis 2018a) that is included as an appendix in a white paper (Arcadis 2018b) that documents this conceptual site model (CSM). The white paper was provided to USEPA and NMED and the findings were discussed in subsequent meetings with the USEPA, NMED, HMC, NRC, and Arcadis. To address technical inquiries from the USEPA and NMED relating to the CSM, HMC has engaged Arcadis to perform a supplemental background investigation at the GRP. This investigation is comprised of four parts: 1) an initial geophysical survey to fill in data gaps relative to subsurface stratigraphy across the alluvial aquifer to the north (upgradient) of the site, 2) selection of locations for boreholes and well installation based on the geophysical survey results, 3) soil and groundwater sample collection and analysis, and 4) data summary and interpretation. The plan for this work is provided here.

1.1 Site History

The NRC licensed boundary of the GRP is 1,085 acres located 5.5 miles north of Milan, New Mexico, in Cibola County. The site is a former uranium mill, owned and operated by HMC, that processed ore from several mines. Milling operations were conducted from 1958 to 1990. Uranium milling was performed using a sodium carbonate solution (alkaline leach) in contact with crushed ore in large tanks. The leached uranium was chemically processed to prepare a concentrated form of uranium for shipment off site. The milling solid waste was managed in two tailing piles: the STP with 1.22 million tons of material covering 40 acres, and the LTP with 21.05 million tons of material covering 234 acres. The groundwater system at the GRP is comprised of an alluvial aquifer and underlying Chinle shale aquifer units, as well as the San Andres-Glorietta aquifer at depth; these systems are part of the lower San Mateo Creek Basin (SMCB). The tailing impoundments were not lined, and in 1976 elevated concentrations of selenium were noted in the alluvial groundwater underneath the LTP. In 1977 a groundwater management strategy was implemented, which was comprised of injection wells downgradient from the LTP to limit migration of impacted groundwater. Extraction wells were also installed, and the beginning of a groundwater restoration strategy was implemented from 1977 to 1982. In 1983 the site was placed on the NPL and a Corrective Action Program (CAP), as required by the RML, was submitted to the NRC in 1989 with updates submitted in 2006 and 2012 (HMC 2012). A comprehensive groundwater restoration strategy has been implemented at the site consisting of flushing of the LTP for control of the source of constituents of concern (COCs), to move pore water from the pile for collection and treatment, groundwater injection and extraction to limit migration of COCs, reverse-osmosis (RO) water treatment for all COCs, and water treatment using a flow-through zeolite system for uranium removal. The groundwater restoration program is authorized and regulated under NRC License SUA-1471 and NMED Discharge Permit DP-200.

The site COCs include selenium, uranium, molybdenum, sulfate, chloride, total dissolved solids (TDS), nitrate, vanadium, thorium-230, and combined radium-226 and radium-228. Groundwater restoration of the alluvial aquifer and underlying Chinle aquifers will proceed until Groundwater Protection Standards (GWPSs) are achieved. The 1989 CAP specified GWPSs for select COCs based on background water quality (i.e., site-specific background standards or SBSs) established through sampling one well in the alluvial aquifer upgradient from the site (well P). The characterization of background groundwater quality in the alluvial and Chinle aquifers was expanded in 2001 based on a set of upgradient wells (DD, ND, P, P1, P2, P3, P4, Q, and R for the alluvial aquifer) and evaluation of data over a 10-year period from 1995-2004 (nine wells, 124 data points). The updated upgradient wells were selected based on USEPA guidance such that the heterogeneity in background water quality entering the GRP was considered. New SBSs for selenium, uranium, sulfate, TDS, and nitrate were calculated according to USEPA guidance for the alluvial aquifer. In 2006, License Amendment #39 proposed the GWPSs for the COCs for each aquifer and included the SBS concentrations developed based on statistical approaches (along with standards for some COCs based on state or federal limits). The GWPSs (including a background concentration of uranium of 0.16 milligram per liter [mg/L] based on an upper 95th percentile of the data set) were accepted by NRC and agreed to by USEPA and NMED. Achieving these GWPSs is the goal of the current groundwater restoration efforts at the GRP.

1.2 Conceptual Site Model

The background water quality, and associated uranium concentration, is dictated by conditions in groundwater unrelated to the operation of the mill at the GRP, predominantly through natural processes. The natural occurrence of uranium in groundwater in the alluvial aquifer upgradient from the LTP and areas of known impacts from LTP seepage is described in a CSM. The CSM describes natural sources of uranium in groundwater and is applicable to the GRP footprint after groundwater restoration is complete, and as such, describes background conditions that will exist in groundwater after areas affected by LTP seepage are restored. The CSM is detailed in a white paper titled "Evaluation of Water Quality in Regard to Site Background Standards at the Grants Reclamation Project" (Arcadis 2018b). The CSM was prepared after completion of the 2016 background groundwater reassessment activities. It is based on the results of the split groundwater sampling event, historical water quality data, and the additional drilling in 2018 that included a soil lithological/mineralogical analysis and geophysical investigation of the alluvial system. The key component of the CSM is a description of natural sources of uranium to groundwater. Erosion and subsequent deposition of uranium-rich deposits from geological formations upgradient from the GRP were part of the formation of the alluvial system. These materials were deposited in discrete lithological horizons that exist in both the saturated and unsaturated zones. The uranium-rich lithologies present in the saturated zone have the potential to cause naturally increased localized uranium concentrations through oxidation and leaching of uranium-bearing minerals. The uranium-rich lithologies were emplaced through natural erosion and deposition of uranium-bearing minerals from bedrock sources lining the basin over hundreds to thousands of years. Depending on the location of eroded uranium-rich outcrops in the north and subsequent transport, and variations in groundwater recharge, the concentration of uranium in the alluvium varies in soils as it varies in groundwater. This results in significant heterogeneity in uranium concentrations in groundwater across the alluvial channel to the north of the LTP; this same heterogeneity in natural uranium concentrations in groundwater is expected to persist after groundwater restoration is complete. The CSM, shown on **Figure 3**, is summarized as follows:

- Weathering and erosion of exposed uranium-bearing formations (Morrison Formation [Jurassic], Dakota Sandstone [Cretaceous], and other associated uranium-rich formations to the north of the site) occurred over hundreds to thousands of years with eroded sediments containing high or low uranium concentrations depending on the source. The highest concentrations of uranium-bearing sediments may have been derived from the northwest based on the density of natural uranium deposits in that area.
- Alluvial material was transported and deposited over hundreds to thousands of years along the alluvial valley by a braided stream channel with varying depositional velocities, resulting in the formation of alternating clay, silt, sand, and gravel layers.
- The concentration of uranium in the deposited sediments depended on the erosional and depositional environment, with the presence of finer-gained sediments (and associated uranium-vanadium bearing clays, sulfide minerals, humate-organic particles, and uraninite/coffinite minerals) frequently associated with higher uranium concentrations.
- Regional groundwater recharge varies across the basin, with groundwater along the east being derived from lower-solute, low-uranium snowmelt from Lobo Canyon.

- Localized dissolved-phase uranium has leached from silt and clay-rich sediment layers within the alluvial sequence in response to natural groundwater geochemistry (elevated alkalinity and TDS), resulting in groundwater containing variable and natural uranium concentrations with depth and spatially across the alluvial channel.

1.3 Data Needs and Study Objectives

Prior work associated with the 2016 split sampling event, geophysics, and borehole development in 2018, has provided significant information on the geology, lithology, and mineralogy, including an enhanced understanding of the existence and form of natural uranium in alluvial sediments in the lower SMCB, immediately upgradient from the GRP. The work to date has resulted in the development of a CSM that describes natural sources of uranium in soil and groundwater, as described in the previous section and illustrated on **Figure 3**. The data have shown that wells used to evaluate the background water quality have not been affected by the LTP or by water flowing from the north with elevated constituent concentrations.

The 2018 borehole development and soil analysis work showed that lithology affects uranium content via grain size and sediment origin. Fine-grained soil is associated with higher uranium, and bedrock units with elevated uranium content (and known to harbor ore-grade uranium deposits) are located upgradient from the west side of the alluvial channel; however, the extent of the distribution of this material throughout the channel is currently not known. In addition, variation in hydraulic conditions in the channel is unknown and important because it affects the leaching of uranium out of naturally occurring minerals. Local heterogeneity of uranium in soils will translate into local variation in uranium concentration in groundwater depending on whether groundwater is fast or slow moving through these lithologic units.

Given that the expectation is that the alluvial channel to the north (upgradient) of the LTP is likely highly heterogeneous (based on variation in water quality across the channel), data are needed to demonstrate (or refute) this spatial variation in lithology and uranium content. This scope of work will fill this data need by showing the lithological and hydraulic heterogeneity across the channel and how they correlate with uranium concentrations in soil and groundwater.

Specific objectives of the 2019 background investigation to fill these data needs are as follows:

- Map alluvial channel geometry and zones containing high permeability coarse-grained materials.
- Estimate the uranium, thorium, and potassium content of the alluvium.
- Obtain lithological, chemical, and mineralogical data of sediments.
- Determine uranium concentrations in groundwater associated with (well screened within) coarse-grained, high-permeability and fine-grained, low-permeability sediments.

1.4 Work Tasks

Geophysical and lithological assessments, including installation of four new wells, and chemical and mineralogical analysis of sediments and groundwater, will meet the background investigation objectives as follows:

- An Electrical Resistivity Tomography (ERT) assessment will provide high-resolution cross-sections of the channel geometry and sediment permeability; results will be used to inform the drilling phase of the program (**Section 2**).
- Downhole geophysical logging, including natural gamma, spectral gamma, and induction conductivity logging of new and existing boreholes/wells, will provide insight into the relationship between the lithology and uranium concentrations as well as guide interpretations of the ERT cross-sections (**Section 2**).
- Lithological assessment and sampling for metals content, mineralogy, and leachability of two new boreholes (BK1 on the western side/BK2 mid-channel of the alluvial basin) will provide a data set to compare to the 2018 boreholes and will guide installation of four new monitoring wells (at these two new boreholes) to target groundwater contained within coarse- and fine-grained sediments (**Section 3**).
- Installation and sampling of one well screened within the coarse-grained sediment and one well screened within the fine-grained sediment at each new borehole location will provide data to further refine and update the CSM for natural uranium placement and transport (**Section 3**).
- Lithological assessment and sampling for metals content, mineralogy, and leachability of one new borehole (BK3) on the eastern side of the alluvial channel will provide new information on the geological and mineralogical characteristics of this portion of the channel to compare to the western/mid side of the basin (**Section 3**).
- Lithological and geophysical assessment at a borehole (BK4) located immediately upgradient of the northwestern corner of the LTP to determine depth to bedrock as well as lithological characterization (**Section 3**).
- A report will be prepared to summarize the drilling, geophysical and lithological assessments, and soil and groundwater sampling results and evaluation (**Section 4**).

1.5 Site-Specific Health and Safety Plan

Site-specific emergency procedures, staff roles and required training, task-specific hazards, safety data sheets (SDSs), required monitoring and personal protective equipment (PPE), traffic control and communications plan, and other site-specific health and safety procedures (e.g., radiological site control and decontamination) are described in the Site-Specific Health and Safety Plan (HASP). The HASP also includes a formal risk assessment (FRA), conducted in collaboration with HMC, for the 2019 background investigation activities.

The HASP includes the following Job Safety Analyses (JSAs):

- Mobilization and demobilization
- Driving
- Site inspection (general safety)
- Utility clearance
- Surface geophysical resistivity assessment

- Hand auguring
- Sonic drilling (includes drilling, sample collection, and well installation)
- Drilling, soil sampling, and well installation
- Downhole geophysical assessment
- Decontamination
- Sample cooler handling.

2. GEOPHYSICAL ASSESSMENTS

Geoscience professionals confront the challenge of understanding the broad context of subsurface conditions, particularly in environments where significant variability in the geologic conditions is evident. Direct observations of geologic materials with drilling technologies is the key means to obtain samples for visual description and a variety of physical and chemical testing procedures to better understand the nuances of the environment. However, direct sampling can be cost prohibitive when dealing with large-scale problems such as the study of the alluvial conditions at the GRP. A practical alternative is to obtain geophysical measurements that can be directly relatable to information obtained at the borehole scale, both along the ground surface and within borings and wells.

Arcadis has considered the specific geologic conditions in the alluvial setting and determined that a viable and cost-effective surface geophysical method to broadly image the subsurface is electrical resistivity imaging along 2-dimensional cross-sections, or tomography for short. The goal of the ERT is to obtain a robust, high-density set of apparent resistivity readings that span the alluvial channel and penetrate to a depth to encounter the underlying bedrock. The raw ERT data sets will be subjected to data processing, which yields a true model of the electrical resistivity of the subsurface. Data obtained at the borehole scale will be incorporated into the interpretation of the ERT images to guide geologic interpretations at and between boreholes. The outcome is expected to provide a direct, continuous image of the bedrock surface beneath the alluvium and internal characteristics of the alluvium at the scale of the geologic sequences or packages of similar lithofacies. Hydrogeologic conditions (degree of saturation and groundwater chemistry) are also expected to be evident because it is essentially pore waters that carry the electrical current in the subsurface.

In addition to the surface geophysical work using ERT, Arcadis has included geophysical measurements within boreholes and wells to provide supporting information and detail at the borehole scale. First, measurements will be made to guide the interpretation of the surface geophysical ERT work. Continuously recorded values of the electrical resistivity of the alluvium outside the well will be gathered in the downhole geophysical phase of work. The technology Arcadis will use to make these measurements does not require direct contact with the alluvium and, therefore, measurements will be made in polyvinyl chloride (PVC) monitoring wells. For the wells located along the ERT section lines, the borehole measurements will be used as *a priori* information to constrain the ERT modeling process as part of the effort to interpret the ERT images. In addition to borehole-scale electrical resistivity measurements, continuous natural gamma logs will also be obtained, which will be invaluable in interpreting the geologic conditions. Finally, borehole-scale measurements of the gamma ray spectra will be made to yield information about the concentrations of potassium, uranium, and thorium in the alluvium. This information will be integral to the interpretation of the origins of the sedimentary facies and the variability of naturally occurring uranium, and, in the case of existing wells (specifically DD, DD2, MV, ND, and Q), will provide information that is otherwise not easily obtained without additional drilling and testing.

2.1 Electrical Resistivity Tomography Assessment

Arcadis will use an ERT assessment to map alluvial channel geometry and the internal variations in the alluvium. The ERT data will be used to inform the drilling phase of the program (see **Section 3**) to determine well positioning and well construction details, including the desired well screen interval.

The key benefit is that this ERT assessment will provide a continuous, broad context for the correlations of the detailed information found within individual boreholes, leading to a more comprehensive and defensible interpretation of the alluvial sediments within the stratigraphic constraints associated with the basin required to outline heterogeneity and potential preferential flow pathways. This is important given the hypothesis that uranium concentrations could be influenced by localized variability tied to the lithology and sediment provenance.

An example of the typical output from an ERT survey is provided in **Exhibit 1**, in which the heterogeneity of alluvial sediments is highlighted. Such an ERT cross-section shows where the highest and lowest hydraulic conductivity zones are based on their corresponding electrical resistivity characteristics in the subsurface and can be very valuable for mapping preferential flow pathways for groundwater based on the distinct electrical resistivity properties of various types of alluvial materials.

Arcadis will conduct the ERT assessment as follows:

- Electrical resistivity data sets will be collected along two roughly parallel east-west transects that span the alluvial channel, where each transect is approximately 7,600 feet in length. The planned approximate locations of the ERT transects are shown on **Figure 4**.
- The ERT setup will utilize 112 electrodes with 6-meter (19.7-foot) inter-electrode spacing. The effective imaging depth of this configuration is approximately 150 feet below ground surface (bgs), which is sufficiently deep to image bedrock in this area.
- A SuperSting R8™ resistivity meter manufactured by Advanced Geosciences Inc. (or equivalent) will be used to collect ERT data.
- A combined dipole-dipole and strong gradient array type will be used to collect ERT data. These combined arrays provide optimal horizontal and vertical sensitivity required to capture the complexities of the stratigraphic environment.
- A total of five overlapping ERT data sets will be collected along each 7,600-foot transect line. Following field data collection, data will be compiled and inverse-modelled to create an electrical resistivity cross-section of the alluvial channel. The RES2DINV software program by Geotomo Software will be used to reduce and inverse-model ERT data. New and existing borehole geophysical (induction conductivity) data will be used to constrain (*a priori*) the resistivity models.
- The location of the electrodes in each ERT transect will be mapped with a high precision global positioning system (GPS) surveying unit.
- The geophysical resistivity tomography work will be performed prior to the installation of any additional boreholes and/or wells as information gained from the sections will be used to more effectively target the drilling assessment(s), based on the lithological interpretation. To the extent possible, existing borehole data will be used to interpret the ERT results, including recent data collected from boreholes DD-BK/DD2-BK as well as newly collected borehole geophysical data from existing wells.

Additional details about ERT field data collection methods and data processing are described in the Sampling and Analysis Plan (SAP) for the 2019 Background Investigation at the GRP, included as **Appendix A**.

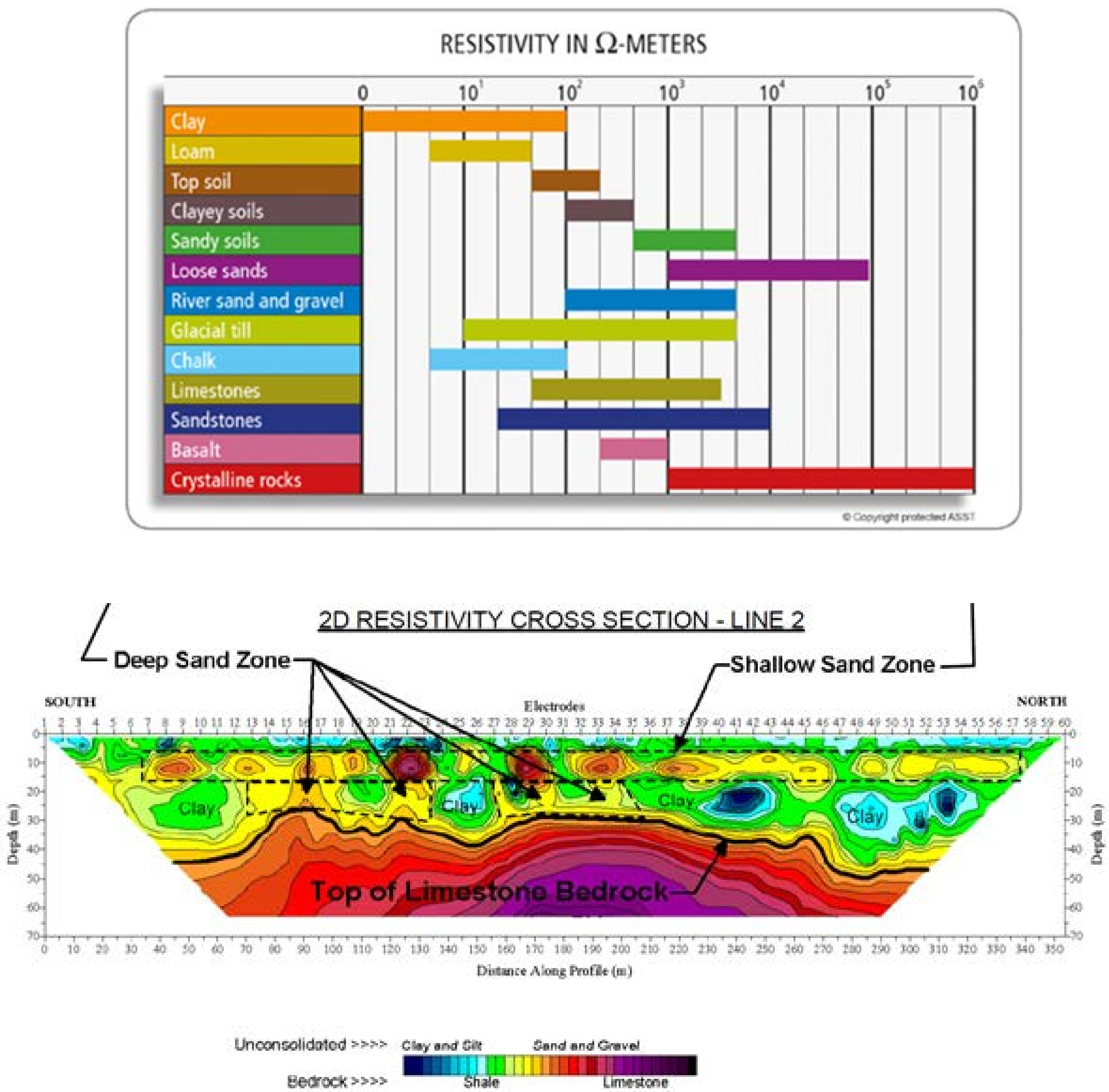

Exhibit 1. Example electrical resistivity tomography results

Resistivity values listed for various lithologies (top) and shown in an actual cross-section (bottom) illustrate how the ERT values can map in-situ geology of unconsolidated lithologies as well as bedrock. Colors in the actual cross-section (bottom) indicate lithologies as listed with the legend in the bottom image and do not correspond with the arbitrary colors shown in the top chart.

2.2 Downhole Geophysical Logging

Downhole geophysical logging has been integral to recent interpretations of the geologic, hydrogeologic, and geochemical conditions within the alluvium (Arcadis 2018b; Harte et al. 2019). Previously existing and newly collected downhole geophysical data will provide a common set of detailed, quantitative, in-situ measurements to link interpretations between visual geologic descriptions and the large-scale ERT cross-sections included in this work plan. Key uses for downhole geophysical data are envisioned to include:

- Lithologic and stratigraphic interpretations in specific locations and along lines of the cross-section to allow inclusion of new and existing wells in the development of the broad interpretations of depositional environments within the alluvium;
- Determination of in-situ concentrations of potassium (K), uranium (U), and thorium (Th) within the alluvium in a continuous manner useful for 1) identifying relationships between naturally occurring uranium and litho-stratigraphic conditions, mineralogy, and geochemical parameters, and 2) interpretation of the provenance of the alluvial sediments using the Th-K ratios and well-established analysis methods (Schlumberger 2009); and
- Calibration and constraint of the ERT inverse models to optimize the geologic interpretations of the alluvium and bedrock. Downhole geophysical data will also provide a direct measure of resistivity conditions and allow for estimation of 1) vertical resolution and uncertainty in the ERT models, and 2) hydraulic parameters such as water saturation, porosity, and possibly grain-related parameters such as grain cementation and tortuosity.

The locations of existing and new wells planned for downhole geophysical logging are illustrated on **Figure 4 (superseded by Appendix C for borehole locations)**. The SAP for this work, included as **Appendix A**, provides detailed descriptions of the logging equipment as well as the data collection and analysis procedures. The types of geophysical data that will be collected are described below.

2.2.1 Method Descriptions

Arcadis will gather three basic types of downhole geophysical data: natural gamma ray (NGR), electrical conductivity (EC), and spectral gamma ray (SGR). All three methods have proven to provide useful information about the alluvial conditions. Moreover, these methods are chosen because the data can be obtained within non-metallic wells. Below are the descriptions each of these methods.

Natural Gamma Ray

NGR logging is a commonly used method to interpret lithology in stratigraphic sediments and rocks. It yields the gross count of natural gamma rays emitted from radioisotopes in the formation, the most common of which is potassium-40 (^{40}K). Orthoclase, biotite, muscovite, illite, smectite, and bentonite are common potassium-bearing minerals that contribute gamma rays. In mature sedimentary environments, coarse materials tend to be depleted of potassium-bearing minerals, and potassium-bearing clay minerals tend to dominate the natural gamma signal in the fine-grained portions of the sediments. Immature coarse-grained sediments that contain significant concentrations of lithic fragments and mineral clasts derived from igneous and metamorphic rocks (felsic to intermediate composition in particular) may be indistinguishable from fine-grained potassium-rich clays, and one of the interpretational pitfalls can be misidentification of lithologies. For this reason, it is a best practice to also collect complementary geophysical data such as point resistance, normal resistivity, or inductive EC because these methods yield information that is directly related to water saturation, water conductance (TDS), porosity, grain-related parameters, and potentially permeability.

Collecting NGR data is relatively simple. No calibration is required in the field (the vendor supplies a certificate of calibration), and the rate of data collection in the hole is relatively high, between 10 and 15 feet per minute. A single value of the total counts per second of gamma rays is stored for each digitized increment (generally 0.1 to 0.3 foot per data point is used).

There is a randomness to the rate of radioactive decay over a short period of time; therefore, raw NGR logs are typically quite noisy. The standard practice for suppressing the random component of the signal to reveal the central trend of the rate of gamma emissions is to apply a weighted average filter to the raw data. Generally, no other processing of NGR data is needed.

The graphical presentation NGR data are useful to identify litho-stratigraphic patterns which can be interpreted in the context of the depositional environment. Subtle vertical changes in clay content not easily captured visually, for example in a fining upwards sequence associated with a meandering stream environment, can be observed in NGR data.

Electrical Conductivity

The inductive EC log provides additional insight regarding the lithology and complements the NGR data, helping to avoid pitfalls as noted above. Unlike NGR, the logging methods that quantify the electrical resistivity or conductivity (the inverse of electrical resistivity) are generally not sensitive to mineral species (in coarse clastics), but instead are sensitive to 1) the specific geometric parameters describing the interconnected grain to grain porosity; 2) the degree of saturation of the fluids that occupy the pore spaces, whether air, water, or both; and 3) the electrical conductance of the groundwater in the pores, which often is strongly related to the TDS. The logging activities will occur in non-metallic wells rather than an open hole; therefore, the best method for this application is the inductive EC method (resistivity logging requires a fluid-filled hole).

One of the most notable responses of EC data is the increase in conductivity within the saturated zone. Once in saturated conditions, generally the less conductive materials tend to be “clean” mixtures of coarse-grained materials low in clays. Within the domain of coarse-grained materials, well-graded/poorly sorted coarse clastics tend to be less conductive than well-sorted/poorly graded coarse clastics. These relationships reflect the combined effects of the grain-related parameters. Note that, if the composition of the coarse materials is uniform and the variability is mainly related to grain-size distribution, the NGR log will likely have only minor variability in a relative sense.

As a rule, the most conductive materials (least resistive) clastics tend to be fine-grained mixtures of silt and clay. Note that clay minerals have a net negative surface charge and interact with ionic species within the pore waters. When electrical current is applied to clays during EC measurements, the loosely bound cations and anions in the clay pores are freed to contribute to the current flow and, as a result, clay-rich sediments are generally very conductive. A generalization can often be made that fine-grained clastics are thus both relatively high in natural gamma rays and EC.

Deviations from the generalized relationships between NGR and EC data can be useful to identify materials in which the source of natural gamma rays is a radionuclide other than ^{40}K (e.g., in uranium-rich materials). In the case of unexpected EC variations, differences in the groundwater chemistry may be the cause. And, as mentioned above, if the clastics are immature, relatively close to the source (e.g., arkose) clastic material may have an EC response corresponding to coarse-grained clastics yet an NGR signature that is akin to clay-rich sediments.

Spectral Gamma Ray

Unlike NGR, which is a gross count of total gamma rays and is represented by a single value, SGR quantifies a broad spectrum of gamma rays, spanning 0 to 3 million electron volts (MeV) of gamma ray energy. Since specific associations between discrete, diagnostic gamma ray energies and radioactive elements exist, in the naturally occurring radioisotope scenario, there is a ***dominant*** set of peaks for the most common elements follows:

- Potassium-40: 1.46 MeV
- Uranium-238: 1.76 MeV
- Thorium-232: 2.62 MeV

Collection of SGR data is generally done initially using a continuous measurement of the gamma spectra at the rate of 1 to 3 feet per minute. This is termed dynamic SGR, and the intent is to identify gross trends in the distribution of K, U, and Th. After interpretation of the dynamic SGR, the well is re-entered and the SGR probe is lowered to specific depths where full quantification of the gamma spectra is desired. This process is termed static SGR. Generally, measurements of the gamma spectra at a given depth are made for a duration of 15 minutes or more. These discrete, data-rich spectra records are summed together (stacked) to greatly decrease random noise and enhance signal.

After data stacking, a modeling process is used to estimate the activity-based concentration (picocuries per gram [pCi/g]) of each of the three elements by 1) isolating, or stripping, the peaks for each element and 2) measuring the height of each peak at the given gamma ray energy levels to arrive at the activity-based concentrations. The mass-based concentration of each element can be calculated from activity-based units using the following relationships empirically determined with specific standard boreholes in which conditions are known. One such set of equations in the public domain is from Appendix A of Stromswold (1994):

- 1 percent (%) K = 8.371 pCi/g of K
- 1 parts per million (ppm) U = 0.3337 pCi/g of U
- 1 ppm Th = 0.110 pCi/g of Th

The dynamic and static SGR results are plotted graphically on the borehole geophysical log along with the other geophysical and geological variables.

Other analysis of the SGR data may also be useful, including the cross-plotting of Th and K. There is a well-studied relationship useful for determining details about the composition of the clastic materials beyond what is possible with natural gamma alone: the overall degree of maturity and weathering of the clastic sediments are reflected in the relative proportions of K and Th in the clays created during the chemical weathering process. Essentially, K is removed from the system as the sediment matures, leaving increasing concentrations of Th, which is very resistant to weathering. **Exhibit 2** illustrates how Th/K can be used to infer the mineralogy of the formation[1].

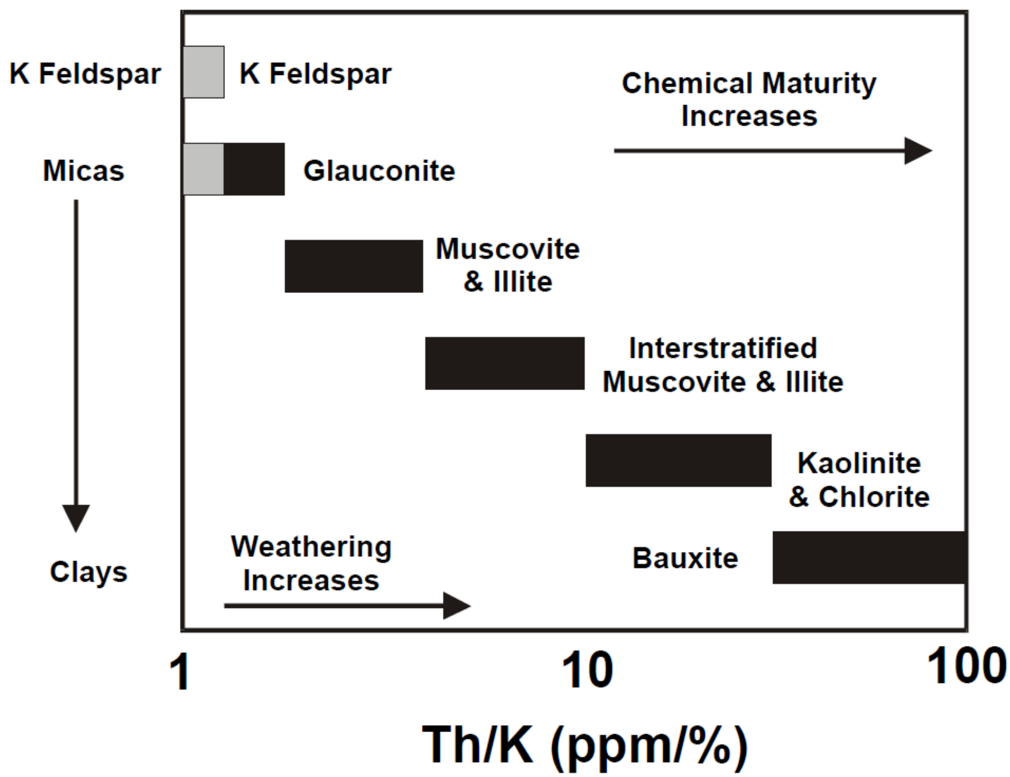

Exhibit 2. Thorium/potassium ratio plot for mineral identification using spectral gamma ray data

1 http://homepages.see.leeds.ac.uk/~earpwjg/PG_EN/CD%20Contents/GGL-66565%20Petrophysics%20English/Chapter%2012.PDF

3. LITHOLOGICAL ASSESSMENT AND INSTALLATION OF MONITORING WELLS

Two locations will be selected for lithological assessment and groundwater monitoring well installation along the geophysical resistivity lines (BK1 and BK2). Soil sampling during advancement of the boreholes will provide geochemical data from both fine-grained and coarse-grained sediments. The groundwater monitoring wells will be installed with short screen intervals separately screened across the fine-grained and coarse-grained sediments, to assess the associated geochemical trends in groundwater.

The results will be used to assess the CSM for natural uranium placement and transport. Groundwater data reflecting that higher uranium concentrations are associated with the finer-grained sediments would indicate that uranium was naturally emplaced during fluvial deposition and is being released into groundwater locally by natural processes.

Conversely, groundwater data reflecting that higher uranium concentrations are associated with the coarser-grained, high hydraulic conductivity sediments could suggest that uranium in groundwater may be present because of regional groundwater sources.

Drilling and installation of the groundwater monitoring wells will be conducted in accordance with the New Mexico Office of the State Engineer Rules and Regulations Governing Well Driller Licensing, Construction, Repair, and Plugging of Wells (19.27.4 New Mexico Administrative Code). The boreholes will be advanced using rotary sonic drilling technique. All drill rig equipment will be decontaminated before drilling operations are begun.

The lithological assessment and monitoring well installation program at each of two sites (precise locations to be determined) along the ERT transects will consist of the following:

- Borehole drilling, lithological assessment, and sampling
- Downhole geophysical assessment
- First groundwater monitoring well installation (screened across coarse sediments)
- Second groundwater monitoring well installation with approximately 50 feet from the first well (screened across fine sediments).

3.1 Borehole Drilling, Lithological Assessment, and Sampling

Six boreholes will be advanced through alluvial materials and 5 feet into bedrock (two at BK1 and BK2, and one each at BK3 and BK4). A geologist will continuously observe all drilling operations, and representative samples of the drill cuttings will be collected and logged at regular intervals during drilling in accordance with ASTM International (ASTM) Designation D2488. Lithologic descriptions will include soil type, color, grade, sorting, matrix, accessory minerals, hardness, and an estimation of moisture content. Observations of the drilling progress will also be captured and logged.

Bedrock is anticipated at a depth of approximately 95 to 105 feet, based on previous drilling in the area. Core will be recovered for the entire borehole length, lithologically logged, and sampled for analysis of metals content, mineralogy, and leachability.

Arcadis will sample sediments for chemical and mineralogical analyses from one borehole at each location based on lithological characteristics and with the intent to obtain representative data for each borehole. Through these analyses, a data set will be generated for these boreholes to compare to data previously collected from boreholes DD-BK and DD2-BK.

Arcadis will perform the following analyses at boreholes BK1, BK2 (on one borehole at each of these locations), and BK3:

- Total metal and radionuclide content by USEPA Method 3050B (hydrochloric/nitric acid digestion) and USEPA Method 6020 (inductively coupled plasma mass spectrometry) – this will provide the concentration of “environmentally accessible” major and trace elements;
- Selective Sequential Extraction (SSE) to evaluate the mineralogy that contains elements of interest – this will include the following fractions: water soluble, exchangeable, carbonate bound, oxide bound, organic bound, and recalcitrant. The extraction chemistries will proceed based on the SSE protocol outlined in Tessier et al. (1979);
- Total organic carbon content on a subset of samples that show the highest uranium concentrations in order to understand the association of uranium with organic carbon, which can retard uranium movement in the subsurface;
- Separation of sediment particles into “light” and “heavy” fractions and analysis of total metals and radionuclides by USEPA Method 3050B with 6020 – this will provide an understanding of the association of uranium and other elements with density-specific mineral fractions;
- Light-microscopy (petrographic microscopy) to evaluate mineralogical characteristics;
- X-ray diffraction to determine major mineralogical content;
- Sulfur stable isotopes on the sediments. Possible pre-processing may be conducted to target sulfides in the samples; and
- Electron/x-ray microscopy/spectroscopy. Prior scanning electron microscopy (SEM) analyses on sediments from boreholes DD-BK and DD2-BK yielded important information about the minerals present, specifically pyrite and oxidized iron sulfides (iron oxyhydroxides), phases that can harbor uranium. The SEM analyses also demonstrated the presence of both reduced and oxidized mineral forms in the sediments and showed that the aquifer environment is dynamic, with redox interfaces present that can result in the dissolution of uranium from natural minerals. One of the challenges was the direct detection of uranium due to its presence at relatively low concentrations. Arcadis will use Quantitative Evaluation of Materials by SCANning electron microscopy or “QEMSCAN” instead, for its ability to automate SEM data collection and improved (better resolution) energy dispersive x-ray spectroscopy data.

Details of the soil sampling program and methods are provided in the SAP, included as **Appendix A**.

3.2 First Well Installation (Coarse Sediments)

The coarse sediment groundwater monitoring well will be installed first during the field activities at each location (BK1 and BK2). The monitoring well borehole will be advanced using a minimum 6-inch-diameter drilling bit. The borehole will be terminated approximately 5 feet beneath the bedrock interface, with the final borehole depth anticipated to be approximately 105 feet bgs. The final borehole depth will depend on the bedrock interface at the time of drilling.

Anticipated well construction details are presented in **Table 1,** and a well construction diagram is presented on **Figure B-1 in Appendix B**. The well will be installed with a 2-inch Schedule 40 PVC casing that extends into the bedrock to enable the downhole geophysics to be conducted, but it will have a short screen interval (5 to 10 feet in length) for targeted groundwater collection. The screen slot size will be 0.01-inch factory slotted screen.

The groundwater monitoring well screen interval will be positioned to target coarse, higher-permeability sediments. The screen placement will be based on the surface geophysical resistivity assessment and refined by core lithological logging during drilling. The base of the well will be sealed with bentonite chips up to within 3 feet of the base of the screen. A 2/12 filter pack sand will be placed in the annulus around the screen to approximately 3 feet above the top of the screen, followed by 5 feet of bentonite chips. The remaining annulus will be filled to the ground with a Portland neat cement grout with 5% bentonite. The exact screen interval and well design will be determined in the field based on the lithology encountered and depth to bedrock.

3.3 Second Well Installation (Fine Sediments)

The fine sediment groundwater monitoring well will be installed second during the field activities at each location (BK1 and BK2). The construction of this groundwater monitoring well will be based on the results of the downhole geophysical assessment, with the screen interval targeting fine-grained sediments.

Well construction details are presented in **Table 1,** and a well construction diagram is presented on **Figure B-2 in Appendix B**. The groundwater monitoring well will be installed with a 2-inch Schedule 40 PVC casing, with a short screen interval (5 to 10 feet in length) for targeted groundwater collection. The screen slot size will be 0.01-inch factory slotted screen. A 2/12 filter pack sand will be placed in the annulus around the screen to approximately 3 feet above the top of the screen, followed by 5 feet of bentonite chips. The remaining annulus will be filled to the ground surface with a Portland neat cement grout with 5% bentonite. The exact screen interval and well design will be determined in the field based on the lithology encountered and depth to bedrock.

3.4 Downhole Geophysical Assessment

As described previously, Arcadis will conduct natural gamma, spectral gamma, and induction conductivity logging in the newly installed boreholes BK1, BK2, BK3, and BK4, sited by the ERT results, cased with 2-inch Schedule 40 PVC riser. Spectral gamma will be performed in two modes: dynamic and static, resulting in data that will provide direct estimation of the K, U, and Th concentrations in the alluvium. The dynamic spectral gamma data will be used to select the static spectral gamma logging locations, and in turn the static spectral gamma will be used to decide which samples to select for laboratory testing. During the same mobilization as the drilling and logging performed at two new locations, downhole geophysical assessments will be conducted on the first borehole at two time periods:

- Initially when the first borehole has reached its total depth and the drill casing is still in place prior to well installation, logging for natural gamma/spectral gamma will be conducted. This will prevent interference by well materials that will be present after well construction (such as bentonite) on the gamma data.

- After installation of the well for the remaining geophysical parameters (induction conductivity).

A discussion of downhole geophysical methods was already provided earlier in this work plan, and additional details are provided in the SAP (**Appendix A**).

3.5 Well Development

The newly installed wells will be developed no sooner than 48 hours after installation to allow adequate time for the well seals to cure. The wells will be developed by surging, bailing, and pumping to remove fine sediment introduced during drilling and/or well construction. During well development, the volume of water extracted and field parameters will be measured, including pH, EC, turbidity, oxidation-reduction potential, dissolved oxygen, and temperature. Development will continue until the turbidity is significantly reduced, targeting readings are less than 5 nephelometric turbidity units, and parameters have stabilized (less than 10% variation in readings).

4. DATA ANALYSIS AND REPORTING

Arcadis will perform the following data evaluation and reporting activities related to the geophysical assessment and borehole/well installation and sampling:

- Model the spectral gamma ray data to calculate the estimated K, U, and Th content of the alluvium. The dynamic data will be reviewed in the field to select the specific static measurement locations. The static data will reflect a higher accuracy and precision than the dynamic data.
- Produce detailed, cross-sectional views of the ERT data to depict the distribution of electrical resistivity variations in alluvial channel sediments and underlying bedrock.
- Produce borehole geophysical graphic logs using WellCAD portraying the geophysical results, visual lithology descriptions, and relevant analytical and mineralogical results to facilitate comparison of the geophysical, observational, and laboratory data.
- Process and evaluate the drilling, geochemical, and geophysical data, comparing lithological variations, geophysical variations, and uranium concentrations with depth.
- Evaluate the borehole sediment chemical and mineralogical results and groundwater results to further refine and update the CSM regarding sources of uranium and other constituents to groundwater upgradient from the GRP.
- Prepare a report to summarize the drilling, soil sampling, geophysical assessment, and data evaluation results. The report will include boring logs and figures of the final boring locations and geochemical results.

Additional information about data collection and data processing is provided in the SAP, included as **Appendix A**.

5. REFERENCES

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WORK PLAN
TABLE

Table 1
Proposed Monitoring Well Construction Details
2019 Background Investigation
Grants Reclamation Project

Location	Well ID	Use	Anticipated Depth to Water (feet)	Approximate Borehole/Well Depth (ft bgs)[1]	Borehole Diameter (inches)	Well Construction Details
Location Along Geophysical Line Number 1 (well pair located within 50 feet of each other)	GF1-CS	Lithological Assessment, Geophysical Logging, and Coarse Sediment Groundwater Monitoring Well	45	105	>6	2-inch PVC Schedule 40 blank casing, with 5-10 feet of 0.010-inch screen, bentonite chip from base borehole to within 3 feet below screen, sand filter pack place adjacent to the screen extending 3 feet above the screen, 5 feet of chip on top of screen, and Portland cement grout with 5% bentonite to surface (installed via tremmie pipe), surface completion with well riser and above ground box with 2-inch J-plug.
	GF1-FS	Fine Sediment Groundwater Monitoring Well	45	70	>6	2-inch PVC Schedule 40 blank casing, with 5-10 feet of 0.010-inch screen, sand filter pack from the base of the well adjacent to the screen extending 3 feet above the screen, 5 feet of chip on top of screen, and Portland cement grout with 5% bentonite to surface (installed via tremmie pipe), surface completion with well riser and above ground box with 2-inch J-plug.
Location Along Geophysical Line Number 2 (well pair located within 50 feet of each other)	GF2-CS	Lithological Assessment, Geophysical Logging, and Coarse Sediment Groundwater Monitoring Well	45	105	>6	2-inch PVC Schedule 40 blank casing, with 5-10 feet of 0.010-inch screen, bentonite chip from base borehole to within 3 feet below screen, sand filter pack place adjacent to the screen extending 3 feet above the screen, 5 feet of chip on top of screen, and Portland cement grout 5% bentonite to surface (installed via tremmie pipe), surface completion with well riser and above ground box with 2-inch J-plug.
	GF2-FS	Fine Sediment Groundwater Monitoring Well	45	70	>6	2-inch PVC Schedule 40 blank casing, with 5-10 feet of 0.010-inch screen, sand filter pack from the base of the well adjacent to the screen extending 3 feet above the screen, 5 feet of chip on top of screen, and Portland cement grout 5% bentonite to surface (installed via tremmie pipe), surface completion with well riser and above ground box with 2-inch J-plug.

Notes:
[1]All depths are approximated and will be determined in the field based on conditions encountered.
ft bgs = feet below ground surface
PVC = Polyvinyl chloride

WORK PLAN FIGURES

CITY: (DENTECH) DIV/GROUP:(ENV) DB:KKELLEY LD: PIC: PM: TM: DATE: 2/11/2019
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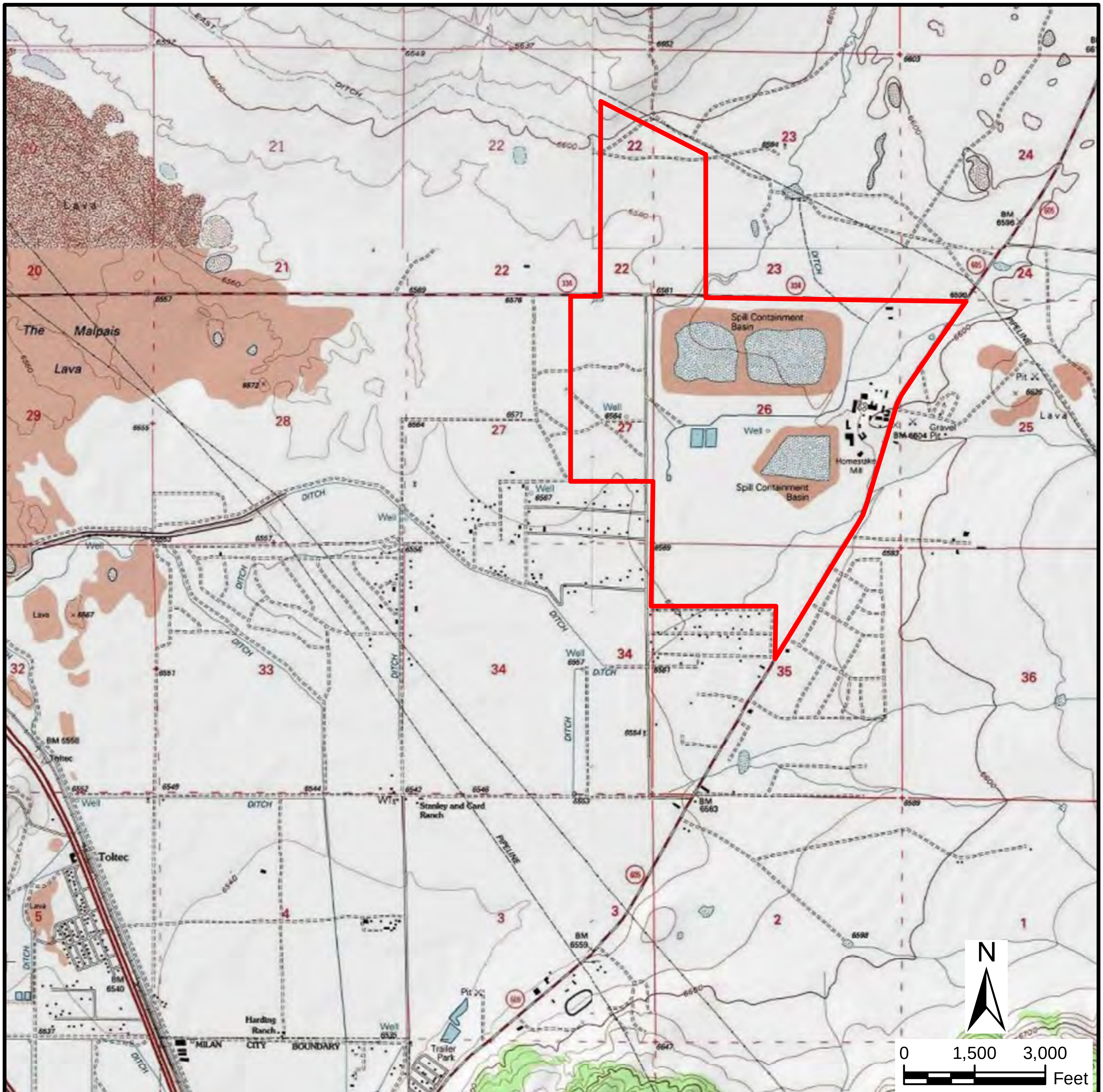


Source: USA Topo Maps, serviced by ESRI ArcGIS Online

LEGEND:

Nuclear Regulatory Commission License Boundary

WORK PLAN
2019 BACKGROUND INVESTIGATION
GRANTS RECLAMATION PROJECT

SITE LOCATION MAP

ARCADIS

FIGURE
1

CITY: (DENTECH) DIV/GROUP:(ENV) DB:KKELLEY LD: PIC: PM: TM: DATE: 2/11/2019
PROJECT: PATH: Z:\GISProjects_ENV\AO000120-Grants\GIS\ArcMaps\2019\Background_Investigation_Work_Plan\Fig_2_Site_Layout_Map.mxd

LEGEND

- RO Sampling Point
- Alluvial Aquifer Well
- Upper Chinle Aquifer Well
- Middle Chinle Aquifer Well
- Lower Chinle Aquifer Well
- 2018 Borehole Location
- Supplemental Monitoring Well Locations for EP-3
- Alluvial Borehole

ND Wells used to derive site-specific background concentrations

DD-BK 2018 Borehole Location

N

0 2,000 4,000

SCALE IN FEET

Basemap features from: Hydro-Engineering, LLC, 2011

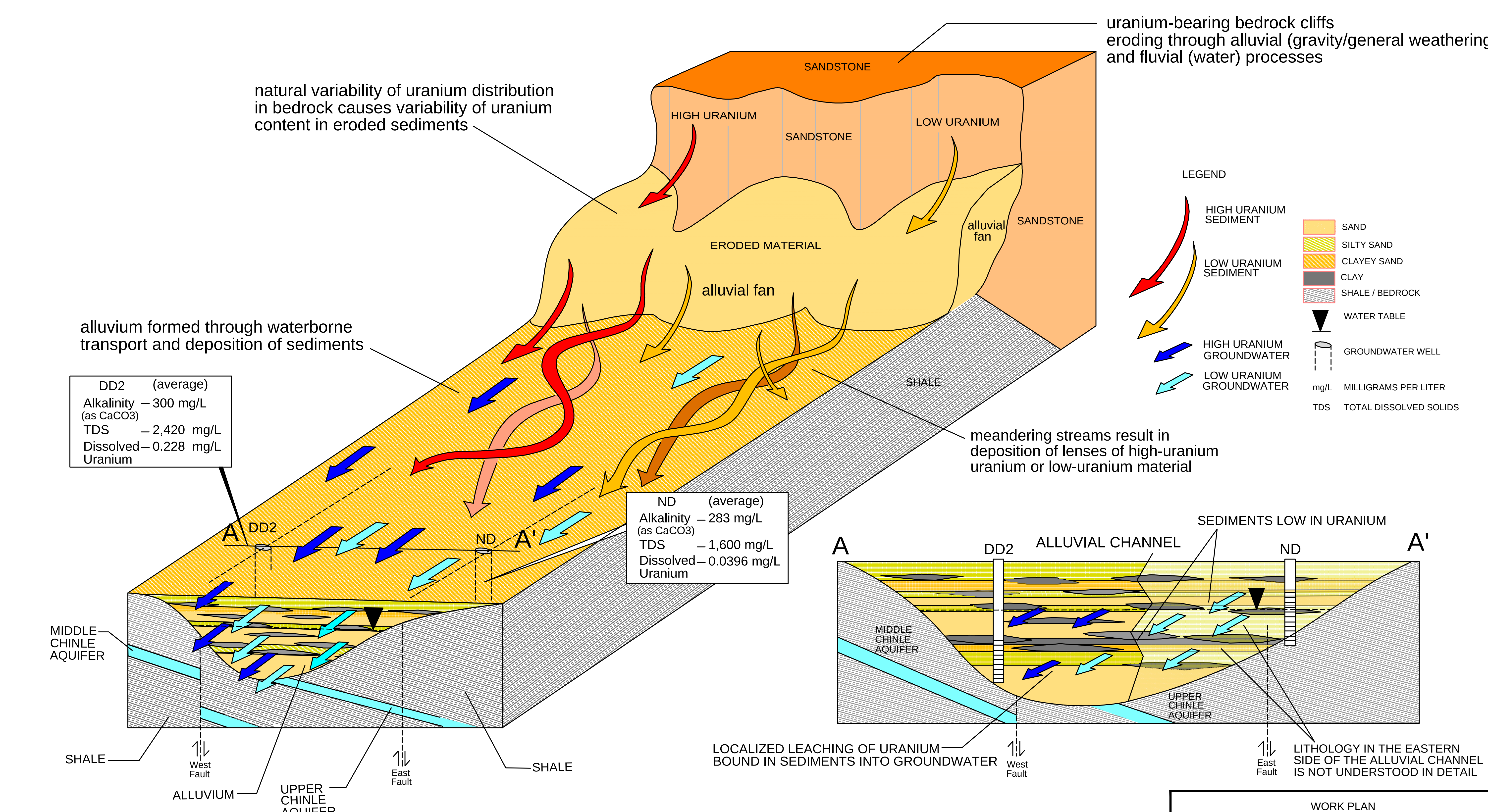
WORK PLAN
2019 BACKGROUND INVESTIGATION
GRANTS RECLAMATION PROJECT

SITE LAYOUT

ARCADIS

FIGURE
2

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



WORK PLAN
2019 BACKGROUND INVESTIGATION
GRANTS RECLAMATION PROJECT

CONCEPTUAL SITE MODEL DIAGRAM

ARCADIS Design & Consultancy for natural and built assets

FIGURE
3

LEGEND

- Existing alluvial aquifer wells planned for downhole geophysical logging including natural gamma, spectral gamma, and induction conductivity (see Note 1)
- New Borehole Locations
- Alluvial Borehole
- Fault
- Proposed Electrical Resistivity Line
- DD-BK 2018 Borehole Location

Subcrop* of Upper Chinle Alluvium Overlies Sandstone
- Saturated Alluvium

Subcrop* of Middle Chinle Alluvium Overlies Sandstone
- Saturated Alluvium
- Unsaturated Alluvium

* Subcrop boundary dashed where inferred.

Notes:
1) Only spectral gamma data will be collected for wells DD, DD2, MV, ND, and Q.
2) Four new borehole locations will be advanced along the resistivity lines; the locations shown on this map are based upon completion of the ERT survey.
3) Four new wells (at locations BK1 and BK2) will undergo downhole geophysical assessment via natural gamma, spectral gamma, and induction conductivity, boreholes BK3 and BK4 will also undergo geophysical assessment.

N

0 2,000 4,000
SCALE IN FEET

Basemap features from:
Hydro-Engineering, LLC, 2011

WORK PLAN
2019 BACKGROUND INVESTIGATION
GRANTS RECLAMATION PROJECT

PROPOSED GEOPHYSICAL ASSESSMENTS AND BOREHOLE LOCATIONS

ARCADIS

FIGURE
4

WORK PLAN
APPENDIX A

Sampling and Analysis Plan

Homestake Mining Company of California

SAMPLING AND ANALYSIS PLAN: 2019 BACKGROUND INVESTIGATION

Grants Reclamation Project
Grants, New Mexico

May 2019

SAMPLING AND ANALYSIS PLAN: 2019 BACKGROUND INVESTIGATION

Grants Reclamation Project
Grants, New Mexico

Prepared for:

Homestake Mining Company of California

Prepared by:

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CO000120.1901

Date:

May 2019

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ACRONYMS AND ABBREVIATIONS

2D	two-dimensional
Arcadis	Arcadis U.S., Inc.
ASTM	ASTM International
^{0}C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
cps	counts per second
CSM	conceptual site model
DQO	data quality objective
EDD	Electronic Data Deliverable
EDS	energy dispersive x-ray spectroscopy
EM	Electromagnetic
ERT	electrical resistivity tomography
GPS	global positioning system
GRP	Grants Reclamation Project
HASP	Health and Safety Plan
HMC	Homestake Mining Company of California
IDW	investigation-derived waste
IT^{2}	Isotope Tracer Technologies
kΩ	kiloohm
LTP	Large Tailings Pile
MS	matrix spike
MSD	matrix spike duplicate
NGR	natural gamma ray
NMED	New Mexico Environment Department
PPE	personal protective equipment
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan

QEMSCAN	Quantitative Evaluation of Materials by SCANning electron microscopy
SAP	Sampling and Analysis Plan
SEM	scanning electron microscopy
SGR	spectral gamma ray
Site	Grants Reclamation Project located in Grants, New Mexico
SOP	Standard Operating Procedure
SSE	Selective Sequential Extraction
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey

1 INTRODUCTION

This 2019 Background Investigation Sampling and Analysis Plan (SAP) presents the methods and procedures Arcadis U.S., Inc. (Arcadis) will use during field activities at the Grants Reclamation Project (GRP) located in Grants, New Mexico (site). Arcadis prepared this SAP on behalf of Homestake Mining Company of California (HMC). The field activities covered in this SAP include geophysical assessments, lithological assessments, the installation of additional groundwater monitoring wells, and soil and groundwater analyses that support this background investigation at the Site. Details of the Arcadis scope of work are provided below. This SAP is meant to cover only those objectives listed in **Section 1.1**.

The GRP is a former uranium mill located 5.5 miles north of Milan, Cibola County, New Mexico, as shown on **Figure 1**. Recent site activities have included groundwater and soil sampling of wells and boreholes in the background area north of the Site to better characterize constituent of concern (COC) distribution in alluvial materials and alluvial groundwater. Further work will be conducted to characterize the nature and distribution of the alluvial materials, their lithology, mineralogy, hydraulic conductivity, and deposition across the alluvial channel. This will include electrical resistivity tomography (ERT) and downhole geophysical logging, lithological assessments of four new borehole cores, collection and analysis of soil samples from two of the new borehole cores, and analysis of groundwater samples from the new wells.

1.1 Objectives

The specific objectives of this SAP are to:

- Develop site-specific data quality objectives (DQOs) (**Section 2**);
- Describe the field methods and locations for investigation activities, including geophysical assessments via ERT and downhole logging, lithological assessments of four new borehole cores, collection and analysis of soil samples from the borehole cores, installation and completion of four new wells, and analysis of groundwater samples from the new wells (**Section 3**);
- Summarize the laboratory analytical program (**Section 3**); and
- Specify field and laboratory quality assurance/quality control (QA/QC) procedures for collecting data that will satisfy the DQOs and are capable of withstanding critical and peer review (**Section 4**).

1.2 Distribution and Revision

Addenda, updates, or revisions to this SAP will be prepared if guidelines, procedures, regulatory documents, or Standard Operating Procedures (SOPs) are revised or when project objectives, scope, or activities change.

The May 2019 revision of this SAP incorporates updates after review by USEPA and NMED and after completion of the ERT survey. Borehole locations BK1, BK2, BK3 and BK4 have been identified and work planned for each of these locations is described herein.

1.3 Work Tasks

This SAP pertains to the following elements of the work plan:

- ERT survey, downhole geophysical survey of existing wells, borehole installation (at BK1, BK2, BK3, and BK4), downhole geophysical survey, and well installation activities (at BK1 and BK2);
- Analysis of soil (recovered from the boreholes (BK1, BK2, and BK3) and groundwater (sampled by HMC after the wells are completed), including the analytical methods to be used;
- Subsurface and above-grade utility location requirements;
- Permitting requirements; and
- Waste management and disposal requirements.

2 PROJECT DATA QUALITY OBJECTIVES

DQOs were developed in accordance with the United States Environmental Protection Agency's (USEPA's) 7-step DQO Process presented in Guidance on Systematic Planning Using the Data Quality Objectives Process, USEPA QA/G-4, EPA/240/B-06/001, February 2006 (USEPA 2006). As described in this guidance, the DQO process is used to develop performance and acceptance criteria (or DQOs) that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. The DQO process identifies the problem, the goal of the study, the information inputs, the boundaries of the study, the analytical approach, the performance and acceptance criteria, and the plan for obtaining data, as follows:

Step 1: State the Problem
Stakeholder groups have requested a better understanding of site-specific background water quality standards and the occurrence of uranium in the alluvial system at the GRP. In 2016, the USEPA, with the assistance of the U.S. Geological Survey (USGS), initiated a reassessment of site background water quality standards and included well reconnaissance, geophysics, and sampling of groundwater via micropurge, volume purge, and passive sampling techniques. HMC engaged Arcadis to collect split samples with the USGS during the 2016 sampling events. Arcadis' interpretation of data collected during split sampling and a subsequent soil investigation is that groundwater uranium concentrations in near-upgradient alluvial wells are attributed to locally naturally occurring uranium in soils. Arcadis prepared a detailed report (Arcadis 2018a) that is included as an appendix in a white paper (Arcadis 2018b) documenting this conceptual site model (CSM). The white paper was provided to the USEPA and New Mexico Environment Department (NMED), and the findings were discussed in subsequent meetings with the USEPA, NMED, HMC, Nuclear Regulatory Commission, and Arcadis. In order to address technical inquiries from the USEPA and NMED relating to the CSM, a supplemental background investigation was deemed necessary.
Step 2: Identify the Goal of the Study
The primary goal of the supplemental background investigation is to refine the CSM for natural uranium distribution and transport by identifying the lithological and hydraulic conductivity heterogeneity as well as the local variation in uranium concentrations across the alluvial channel upgradient (north) of the large tailing pile (LTP).
Step 3: Identify Information Inputs
The data needed to accomplish the goals of the supplemental background investigation are as follows: • Lithology and stratigraphy of the alluvial channel north of the LTP, including visualization of channel geometry and high-permeability zones containing coarse-grained materials; • In-situ alluvium concentrations of uranium, thorium, and potassium to 1) identify relationships between naturally occurring uranium and litho-stratigraphic conditions, mineralogy, and geochemical parameters, and 2) interpretation of the provenance of the alluvial sediments using the thorium-potassium ratios;

- Mineralogical and geochemical data as well as uranium and other element concentrations from both fine-grained and coarse-grained sediments; and
- Temporal trends in geochemical data and uranium concentrations in groundwater associated with (i.e., separately screened across) fine-grained and coarse-grained sediments.

Step 4: Define the Boundaries of the Study

Geophysical, lithological, and sampling activities to obtain the data needed to support the goals of the supplemental background investigation will include new boreholes and wells located along a cross-section across the alluvial channel as well as existing alluvial aquifer wells north of the LTP at the GRP.

Step 5: Develop the Analytical Approach

Geophysical assessments include an ERT assessment and downhole geophysical logging.

- ERT assessment data will be used to inform the drilling phase of the program as well as to map the alluvial channel geometry and high-permeability zones.
- Downhole geophysical logging of existing and new boreholes/wells will provide a common set of detailed, quantitative, in-situ measurements to link interpretations between visual geologic descriptions, lithology of alluvial material surrounding existing monitoring wells where visual descriptions may be unavailable or of low detail, and the large-scale ERT cross-sections.

Lithological assessment and installation of two groundwater wells will be conducted at two different locations along the ERT transects.

- Soil sampling during advancement of the boreholes will provide geochemical data from both fine-grained and coarse-grained sediments.
- The groundwater monitoring wells will be installed with short screen intervals separately screened across the fine-grained and coarse-grained sediments to assess the associated geochemical trends in groundwater.

The results will be used to refine the CSM.

- Groundwater data reflecting that higher uranium concentrations are associated with the finer-grained sediments would indicate that uranium was naturally emplaced during fluvial deposition and is being released into groundwater by natural processes.
- Conversely, groundwater data reflecting that higher uranium concentrations are associated with the coarser-grained, high hydraulic conductivity sediments could suggest that uranium in groundwater may be present because of regional groundwater sources.

Step 6: Specify Performance or Acceptance Criteria

Measurement performance criteria are specified in the Quality Assurance Project Plan (QAPP) for the GRP included as **Appendix A** of this SAP.

Step 7: Develop the Plan for Obtaining Data

This SAP presents the rationale and plan, including field and analytical methods, for obtaining geophysical, lithological, and soil and groundwater sampling data.

3 INVESTIGATION ACTIVITIES AND METHODS

This section describes the field methods and locations for the following investigation activities: geophysical assessments via ERT and downhole logging (in existing and new wells), lithological assessments of four new borehole cores, collection and analysis of soil samples from two of the borehole cores, installation and completion of four new wells, and analysis of groundwater samples from the wells.

3.1 Geophysical Assessments - Electrical Resistivity Tomography and Borehole Logging Upgradient from the LTP

3.1.1 Electrical Resistivity Tomography Assessment

Arcadis will use an ERT assessment to map alluvial channel geometry and zones containing high-permeability coarse-grained materials. The ERT data will be used to inform the drilling phase of the program (see **Section 3.1.2**) to determine well positioning and well construction details, including the desired well screen interval.

Electrical resistivity is an intrinsic property of materials that varies widely in the subsurface and often correlates with lithology and geochemistry. For soils and rock, resistivity is a function of porosity, ionic content of the pore fluids (usually groundwater), and electrically conductive/reactive minerals such as pyrite and some clay minerals. By measuring the distribution of resistivity values in the subsurface, the presence and structure of geologic features can be inferred. For the Site, it is assumed that alluvial sediments composed of coarser-grained sand and gravels will display higher resistivity values relative to fine-grained silts and clay sediments.

3.1.1.1 ERT Field Data Collection

The geophysical resistivity tomography work will be performed prior to the installation of any additional boreholes and/or wells as information gained from the sections will be used to more effectively target the drilling assessment(s), based on the lithological interpretation. To the extent possible, existing borehole data will be used to interpret the ERT results, including recent data collected from boreholes DD-BK/DD2-BK as well as newly collected borehole geophysical data from existing wells.

Electrical resistivity data will be collected along two east-west transects that span the alluvial channel, where each transect is approximately 7,600 feet in length, as illustrated on **Figure 2**. A combined dipole-dipole and strong gradient array type will be used to collect ERT data. These combined arrays provide optimal horizontal and vertical sensitivity required to capture the complexities of the stratigraphic environment. A total of five overlapping ERT data sets will be collected along each 7,600-foot transect line. The location of the electrodes in each ERT transect will be mapped with a high-precision global positioning system (GPS) surveying unit.

The ERT geophysical survey instruments will include:

- Advanced Geosciences, Inc., Super Sting R8TM electrical resistivity meter (or equivalent) and switch boxes, specialized electrical resistivity cables with up to 112 individual electrodes with maximum spacing of 6 meters, and stainless-steel electrode stakes for making ground contact. The effective imaging depth of this configuration is approximately 150 feet below ground surface.

Before the electrical resistivity survey begins, the electrodes and cables undergo a contact resistance test, which tests the integrity of each electrode coupling and ensures that the electrical resistance between the electrode and the soil material is appropriate to produce quality resistivity measurements. Salt water will be added around the electrodes to improve contact resistance. Lowering of contact resistance improves the ability to inject current. Arcadis generally uses a cutoff of 20 kiloohms (kΩ) for surface data. Higher values may indicate that limited current can be injected for that electrode pair. It is important to witness the contact resistances and record them manually to determine the quality of contact. Note that the Super Sting automatically records the contact resistance for later use, but it is not easily reviewed in the field. Contact resistance values can provide a basis for editing data associated with electrodes that are malfunctioning or in poor contact with the formation. The survey will not begin until an adequate contact resistance test is completed.

In addition, utilities within 30 feet of the resistivity transects will be marked on the ground, so that resistivity anomalies from utilities can be identified in the data collected. Metallic well casings tend to create an especially strong anomaly; therefore, layout of the resistivity transects will avoid well casings by at least 30 to 50 feet, if possible.

3.1.1.2 ERT Data Processing

Following field data collection, acquired ERT data sets will be transferred to a computer and processed to create modelled cross-sections that are prepared for geologic interpretation by an experienced geophysicist. The two-dimensional (2D) ERT data will be reduced and processed using the RES2DINV software program by Geotomo Software. Prior to data modelling, a number of pre-processing steps will be completed, including removal of data with voltage spikes, poor voltage decay, and low data quality readings in the raw field data.

Resistivity data will be processed using a damped least-squares or smooth model inversion method using a finite element mesh to generate a 2D model of resistivity versus depth. The primary objective of inversion is to reduce data misfits between field measurements and calculated data of a reconstructed model. New and existing borehole geophysical (induction conductivity) data will be used to constrain (*a priori*) the resistivity models.

Final graphical representations of the results will show areas in which data were removed to provide confidence that the final inverted image was produced with sufficient data coverage. Areas with inadequate data coverage will be designated as questionable for interpretation.

Final modelled ERT data will be presented as cross-sectional views of the subsurface that depict the distribution of electrical resistivity variations in subsurface materials along a single line of data collection.

3.1.2 Downhole Geophysical Logging

During the same mobilization as the drilling and logging performed at four new locations along the resistivity lines, additional downhole logging will be performed at a sampling of existing wells to gather a distribution of lithologic and chemical results in a variety of locations, upgradient and downgradient, west and east, as shown on **Figure 2**. Arcadis will conduct natural gamma ray (NGR), spectral gamma ray (SGR), and induction conductivity logging in a number of existing wells at the Site (R, P2, P4, 914, 920, 921, 922, W, and L), and only SGR in an additional five wells (DD, DD2, MV, ND, and Q). Additionally, NGR, SGR, and induction conductivity will be conducted in the newly installed boreholes, sited by the ERT results, cased with 2-inch Schedule 40 polyvinyl chloride (PVC) riser. SGR will be performed in two modes, dynamic and static. This approach will result in data that will provide direct estimation of the potassium, uranium, and thorium concentrations in the alluvium. The dynamic SGR data will be used to select the static SGR logging locations, and in turn the static SGR will be used to inform the decisions on which samples to select for laboratory testing.

The totality of the geophysically logged locations will be used to:

- Augment the existing descriptive logs to provide improved, detailed lithology estimates for older, existing wells;
- Provide additional insight into the relationships between sediment types and uranium concentrations;
- Analyze the thorium and potassium data to further develop the concept regarding sediment provenance; and
- Guide the interpretations of the ERT cross-sections.

Logging Equipment

Arcadis will collect downhole geophysical logs using a portable Matrix system manufactured by the Mount Sopris Instrument Company in Golden, Colorado. This system is a digital, multi-channel system designed primarily for shallow environmental and engineering studies. The logging system consists of two primary components. The first component is the integrated logging control unit, which remains at the surface with the equipment operator, and the second component is the downhole-logging probe. The control unit is joined physically and electronically to the chosen downhole probe with a steel cable, approximately 600 feet in length, containing a single insulated signal wire. The steel cable is spooled on an integrated electric winch mechanism. The downhole position of the probe is measured to a precision of 0.01 foot with a digital odometer. The electrical signals transmitted by the downhole probe are passed from the winch to a signal processor within the logging unit. Therefore, the processed digital data collected includes the probe depth, speed, and probe-specific measurements of the borehole. The data are recorded in a portable computer for real-time viewing and storage for later analysis.

The proposed geophysical probes to be used include:

1) Electromagnetic (EM) conductivity probe
2) NGR probe
3) SGR probe.

The individual probes are further discussed in the subsections below.

EM Conductivity Probe

A Mount Sopris 2PIA-1000 EM conductivity probe will be used to provide information on the geologic strata beneath the Site. The operating principal for the EM probe is that the intensity of an induced secondary electromagnetic field is directly proportional to the electrical conductivity/resistivity of materials such as rocks, soils, and fresh water. In freshwater environments, clay-rich sediments/rocks generally have lower electrical resistivity than do sands because there are layers of unbound cations and anions adsorbed to the outer surfaces of the clay minerals. In the presence of electrical current, these cations and anions are free to move and carry the electrical current. Similarly, fractured/weathered bedrock is much less resistive than competent bedrock. Data from this probe are output in electrical conductivity readings of milliSiemens per meter (mS/m).

The EM conductivity probe is relatively temperature sensitive, and site-specific calibration is necessary prior to logging. The manufacturer's calibration procedure will be performed prior to logging.

NGR Probe

A Mount Sopris 2PGA-1000 natural gamma probe will be used to provide information about the total level of natural gamma radiation emanating from subsurface stratigraphy. The 2PGA-1000 probe is a high sensitivity scintillometer that measures the gross NGR count. It has a relatively large sodium iodide crystal that optimizes the instrument sensitivity to the types of gamma rays generally encountered in clay minerals, as well as those from other naturally occurring radioactive elements and minerals. The data are presented in units of gamma ray counts per second (cps). Most NGR emissions are caused by minerals containing potassium, uranium, and/or thorium. While clay minerals (which contain the radioactive isotope potassium-40) are generally the most commonly observed natural gamma emitters, natural uranium may also be present on this Site. In contrast, geologic layers that contain little to no clay minerals (or other radioactive elements) emit very few gamma rays.

No field calibration is needed for the NGR probe. The manufacturer will provide a certificate of calibration for the specific probe used.

SGR Probe

A Mount Sopris 2SNA-1000-S spectral gamma probe will also be used to measure the natural gamma radiation emanating from the various geologic strata; however, this probe will split the total response into the various contributions from each of the major radio-isotropic sources. As such, this will allow the SGR log to differentiate between the NGR response of clay minerals (potassium-40), the uranium-radium series, and the thorium series, based on the energy level of each gamma ray encountered. Similar to the NGR probe, the 2SNA-1000-S also uses a high sensitivity scintillometer to measure the gamma ray count, and, once the counts have been separated into the various radio-isotropic components, they are presented in units of cps.

No field calibration is needed for the spectral gamma probe. The manufacturer will provide a certificate of calibration for the specific probe used.

Data Collection Procedures

Downhole logs from the three probes will be collected in each of the four boreholes, which will be cased in 2-inch solid PVC risers. The three logs per borehole will be collected in dynamic mode, at a rate appropriate for each probe per manufacturer's guidance. Additionally, static data will be collected from the SGR probe at key depth intervals selected from the dynamic data set for a time range of 10 to 15 minutes. This approach will result in data that will provide direct estimation of the uranium concentration in the alluvium. The static SGR will be used to decide which samples to select for laboratory testing.

During geophysical logging, Arcadis plans to document the activities conducted at each well, including at a minimum:

- Names of each personnel present
- Weather conditions
- Date and time of measurements
- Well details, including ID, diameter, total depth, screened interval, and static depth to water
- Tools being run and tool condition
- Tool calibration
- Logging speeds
- Depths evaluated
- Reproducibility of data acquisition
- Preliminary results (e.g., casing conditions)
- Decontamination procedures.

Observations of geophysical logging will be recorded on the geophysical logging observation form provided in **Appendix B**. Additionally, a field notebook will be maintained in accordance with the SOP for Field Log Book Entries (**Appendix C**). Arcadis personnel will also take representative photographs to document geophysical logging activities.

Data Analysis Procedures

The data collected from each of the logging probes will produce an integral data file developed specifically for importation into a data analysis and plotting program called WellCAD Version 5.2.

3.2 Lithological Assessment and Installation of Additional Wells

Arcadis will install four groundwater monitoring wells as part of this phase of the background study, at locations BK1 and BK2. Installation of four boreholes/groundwater monitoring wells will enable targeting of both coarse- and fine-grained sediments at the two locations selected for assessment along the geophysical resistivity lines. Soil sampling during advancement of the boreholes will provide geochemical data from both fine-grained and coarse-grained sediments. The groundwater monitoring wells will be installed with short screen intervals separately screened across the fine-grained and coarse-grained sediments to assess the associated geochemical trends in groundwater. The results will be used to assess the CSM for natural uranium placement and transport.

The lithological assessment and monitoring well installation program will consist of the following:

- Borehole drilling, lithological assessment, and sampling
- Downhole geophysical assessment
- First groundwater monitoring well installation (screened across coarse sediments)

- Second groundwater monitoring well installation (screened across fine sediments).

3.2.1 Drilling, Lithological Assessment, and Soil Sampling

Two boreholes will be drilled initially with locations (BK1 and BK2) based on the results of the ERT survey (see **Section 3.1.1**). Initial boreholes at each of two locations will be advanced through alluvial materials and 5 feet into bedrock. Bedrock is anticipated at a depth of approximately 95 to 105 feet, based on previous drilling. Core will be recovered for the entire borehole length, lithologically logged, and sampled for analysis of metals content, mineralogy, and leachability.

A geologist will continuously observe all drilling operations, and representative samples of the drill cuttings will be collected and logged at regular intervals during drilling in accordance with ASTM International (ASTM) Designation D2488. Lithologic descriptions will include soil type, color, grade, sorting, matrix, accessory minerals, hardness, and an estimation of moisture content. Observations of the drilling progress will also be captured and logged.

Based on the lithological assessment of the first two boreholes, two additional boreholes will be drilled for fine sediment wells. These boreholes will not necessarily be drilled to bedrock but will instead be drilled only to the depth of the targeted fine sediment, which is anticipated at approximately 60 to 70 feet below ground surface.

Soil sampling will be conducted as diagrammed in **Tables 1 and 2**. Sampling will be completed in a discretionary manner, targeting varying lithologies. During soil sampling, Arcadis plans to record, at a minimum, the following information:

- Name of each person present
- Sample dates and times
- Weather conditions
- Equipment and QA/QC procedures
- Sample preparation and field storage methods.

A field notebook will be maintained in accordance with the SOP for Field Log Book Entries (**Appendix C**). Arcadis personnel will also take photographs to document drilling and soil sampling activities.

The following analyses will be performed on soil samples collected from the first two boreholes, as well as borehole BK3 (**Table 1**):

- Paste pH, and oxidation-reduction potential (ORP) on soil
- Total metal and radionuclide content by USEPA Method 3050B (hydrochloric/nitric acid digestion) and USEPA Method 6020B (inductively coupled plasma mass spectrometry) – provides the concentration of "environmentally accessible" major and trace elements; up to 20 samples will be obtained for this analysis, with 10 samples taken from each initial borehole, targeting various lithologies. One additional sample will be submitted as a field duplicate, for a total of 21 samples.
    - o Major elements that will be analyzed include aluminum, calcium, magnesium, potassium, sodium, silicon (often reported as silica), iron, and manganese. Trace elements and radionuclides include

molybdenum, selenium, uranium, and vanadium. This set of analytes is heretofore referred to as the “elemental suite.”

- Analysis of total metals and radionuclides in density fractionated splits by USEPA Method 3050 with USEPA Method 6020B – provides an understanding of the association of uranium and other elements with specific mineral fractions, based on particle density. This analysis will be performed on 10 gravity fractionated splits and analyzed for the elemental suite.
- Selective Sequential Extraction (SSE) to evaluate the mineralogy that contains elements of interest in the following mineralogical fractions: water soluble, exchangeable, carbonate bound, oxide bound, organic bound, and recalcitrant (discussed further below) – up to 10 samples will be submitted for this analysis. Sample selection will be based on the initial results of the total metals analysis (one duplicate will be included in these 10 samples). The samples will be analyzed for the elemental suite, as well as sulfate, carbonate, and phosphate on the leachate from Step 1 (water soluble) and sulfate and phosphate on Step 2 (adsorbed) Note that the draft plan included a second step that has been changed from an exchangeable fraction that would include a magnesium chloride extraction to an alkaline leach solution as was used in the DD-BK and DD2-BK samples in 2018. This change allows data to be compared to other work completed and ongoing on alluvial sediment samples on-site, and it allows us to compare leachate from step 2 to SPLP leachate from the 2018 DD-BK/DD2-BK work. This change also eliminates the concern about whether calcium or magnesium is a better competitive displacer for uranium in the sediment samples; an exchangeable step may be less relevant to understanding uranium lability in sediments, and it is important to incorporate an alkaline leach step given the alkalinity of groundwater in the area.
- Total organic carbon and total sulfur content using the LECO induction furnace method on a subset of samples that show the highest uranium concentrations (up to five samples) – provides the association of uranium with organic carbon and sulfur.
- Light-microscopy (petrographic microscopy) to evaluate mineralogical characteristics in five samples.
- X-ray diffraction to determine major mineralogical content in five samples.
- Stable sulfur isotopes as analyzed by Isotope Tracer Technologies (IT2) Laboratories, Waterloo, Ontario, Canada – this will be performed on five samples. Possible pre-processing may be conducted to target sulfides in the samples through the oxidation of the sample with bromine.
- Electron/x-ray microscopy/spectroscopy (discussed below).

A summary of the soil analyses is provided below in **Exhibit 1**. A detailed summary of the sampling program, including laboratories chosen for each analysis, is provided in **Table 2**. Preservation requirements and method holding times are included in **Table 3**.

Exhibit 1. Summary of soil analyses to be performed on three new boreholes at the GRP

Analysis	Number of analyses[1]
Total metals, USEPA Method 3050B/6020[2]	10 per borehole (30 total)
Selective sequential extraction	15 total

Analysis	Number of analyses[1]
Total organic carbon and total sulfur content, LECO induction furnace[2]	15 total
Petrographic microscopy	8 total
XRD	8 total
Soil sulfur isotopes	8 total
QEMSCAN[3]	2 total

[1]Analysis of up to the total number of samples shown may be conducted.

[2]Sampling will include one duplicate analysis for a total of 21 samples.

[3]Analytical techniques are being identified that can detect uranium at the low concentrations that occur in these samples; a different type of analysis may be substituted for QEMSCAN if it is determined to be more appropriate for this task.

Selective Sequential Extraction

Ten samples will be subjected to SSE; the samples selected for this analysis will be based on the results of the total metals analysis, combined with the lithological evaluation, such that samples that contain uranium at various concentrations and across a range of lithologies (from sands to fine silts/clays) are selected. The SSE method uses chemical reagents that selectively dissolve individual phases or mineral forms of the target element under investigation, in this case uranium. The reagents range in chemical strength and are progressively stronger in terms of their ability to dissolve mineral phases. The results of this analysis will provide an indication of the leachability of each element based on the phase within which it predominantly resides (e.g., if 85 percent of the total uranium is found to be liberated in the water soluble fraction, then it is likely that uranium present in the sample is readily released into groundwater).

Extraction chemistries will proceed based on the SSE protocol outlined in Tessier et al. (1979) and summarized in **Table 4**. The details of the extraction procedure will be provided to the laboratory that will perform this work (ACZ Laboratories in Steamboat Springs, Colorado). A 2- to 5-gram sample of soil will be used, dried to determine the dry weight, and ground prior to the SSE. The steps in the sequential extraction and reagents are described below:

Extraction Step 1: Water Soluble

This step will extract uranium and other elements that are readily dissolved in water. Distilled water will be added to soil and shaken for 1 hour and then centrifuged at 12,000x gravity force for 30 minutes, with the supernatant recovered and analyzed for the elemental suite as well as sulfate, phosphate, and carbonate..

Extraction Step 2: Adsorbed

This step will extract uranium and other elements that are displaced by bicarbonate/carbonate, simulating interaction of the soil with groundwater chemical conditions relevant to the alluvial aquifer (specifically the presence of alkalinity that can enhance uranium solubility). A reagent consisting of 0.014M sodium bicarbonate and 0.003 M sodium carbonate will be added to soil and shaken for 1 hour, followed by rinsing with deionized water. The supernatant will be analyzed for the elemental suite as well as sulfate and phosphate.

Extraction Step 3: Carbonate Bound

This step will extract elements that are associated with carbonate minerals; dilute sodium acetate will be used (1 molar, adjusted to pH 5 with acetic acid). The sample will be shaken for 2.5 hours with venting to liberate any evolved gases, centrifuged, and the supernatant will be analyzed for the elemental suite.

Extraction Step 4: Oxide Bound

This step will extract elements that are associated with amorphous and crystalline iron- and manganese-oxides. Dilute hydroxylamine hydrochloride (0.04 molar) in 25 percent by volume acetic acid will be used, with the sample heated at 96 ± 3 degrees Celsius (°C) for 6 hours. At the end of the digestion, the sample will be centrifuged and the supernatant will be analyzed for the elemental suite.

Extraction Step 5: Organic Bound

This step will extract elements that are associated with organic carbon. The extraction reagent will consist of ammonium acetate (3.2 molar) adjusted to pH 2 with nitric acid, and the sample will be heated at 85 ± 3°C for 2 hours. After heating, concentrated hydrogen peroxide will be added (adjusted to pH 2 with nitric acid) followed by heating at 85 ± 3°C for 3 hours. The supernatant will be recovered and analyzed for the elemental suite.

Extraction Step 6: Residual

The final step in the SSE will digest any remaining material – this step will dissolve the "recalcitrant" or residual elements that are tightly bound to the soil and virtually insoluble. USEPA Method 3052 will be used for this extraction step; this employs concentrated nitric, hydrochloric, and hydrofluoric acids. The digested material will be analyzed for the elemental suite.

As a data evaluation/quality control measure, the concentration of the elements in each extraction step (prior to the residual [3052] extraction step) will be summed and compared to the results of the 3050B digestion, performed separately on the samples, in order to develop a mass balance that will inform how well the recovery from each individual step matches with the total concentration of each element. The data will be reported as the concentration of each element extracted in each step, as well as the fraction of each element associated with each targeted phase.

Scanning Electron Microscopy (SEM)

QEMSCAN will be used to analyze two samples selected based on the total metals content and lithologic description, with preference given to those samples that contain the highest concentrations of uranium. This method will be used instead of conventional SEM because of its ability to automate SEM data collection and improved (better resolution) energy dispersive x-ray spectroscopy (EDS) data. Soil samples will be embedded in epoxy and polished so that the surface is of optimal (smooth) roughness for the analysis. Automated mapping of the elemental composition of the sample will be performed with a focus of the analysis on locating uranium, and its elemental association. In addition, the size of the uranium-bearing particles will be identified along with the general morphology of the particles. Due to the possibility that the uranium concentrations are too low to be detected via EDS, additional sample analysis techniques are currently being investigated. If it is determined that a different technique would yield better spatial data related to uranium distribution in these samples, QEMSCAN may be replaced with the more advantageous method. In additional, sample preparation methods based upon particle size fractionation and mineral density are being evaluated for their utility in enhancing the success of QEMSCAN analysis.

3.2.2 Downhole Geophysical Assessment

During the same mobilization as the borehole drilling and logging, as described above, downhole geophysical assessments will be conducted on all of the boreholes (BK1 through BK4). Due to potential interactions between the downhole geophysical tools and well completion materials (e.g., bentonite), downhole geophysical assessments will be conducted at two time periods on each initial borehole (BK1 and BK2):

- When the first borehole has reached its total depth and the drill casing is still in place prior to well installation, logging for natural gamma/spectral gamma will be conducted. This will prevent interference by well materials that will be present after well construction (such as bentonite) on the gamma data.
- After installation of the well, induction conductivity will be conducted.

Downhole logging will be performed as described in **Section 3.1.2** of this SAP.

3.2.3 Well Installation

Four wells will be installed, two at each of the two initial borehole locations (BK1 and BK2), as follows:

- First Well Installation at Each Location (Coarse Sediments): This groundwater well screen interval will be placed to target coarse, higher-permeability sediments. The screen placement will be based on the surface geophysical resistivity assessment and refined by core lithological logging. The well will be installed with a 2-inch Schedule 40 PVC casing that extends into the bedrock to enable the downhole geophysics to be conducted, but it will have a short screen interval (5 to 10 feet in length) for targeted groundwater collection. The screen section will be hydraulically isolated by placement of bentonite chips both above and below the screen interval.
- Second Well Installation (Fine Sediments): The construction of this groundwater well will be based on the results of the downhole geophysical assessment, with the screen interval targeting fine-grained sediments.

The newly installed wells will be developed no sooner than 48 hours after installation to allow adequate time for the well seals to cure. The wells will be developed by surging, bailing, and pumping to remove fine sediment introduced during drilling and/or well construction. During well development, the volume of water removed and field parameters will be measured, including pH, electrical conductivity, turbidity, oxidation-reduction potential, dissolved oxygen, and temperature. Development will continue until the turbidity is significantly reduced, targeting readings less than five nephelometric turbidity units and parameters have stabilized (less than 10 percent variation in readings).

Anticipated well construction details and well installation and development procedures are discussed in the Work Plan: 2019 Background Investigation at the GRP.

3.3 Groundwater Sampling

Groundwater well sampling will be conducted on the newly installed wells by HMC staff at least 48 hours after well development.

3.3.1 Water Level Measurement

Static water level measurements will be collected using a water level indicator prior to conducting purging and sampling activities. Static water levels will be measured relative to surveyed datum (i.e., top of well casing) to the nearest 0.01 foot and recorded in the appropriate field logbook or groundwater sampling form. Field staff will collect water level measurements in accordance with the SOP for Water Level Measurement (**Appendix C**).

3.3.2 Field Parameter Measurement

Field parameters (temperature, pH, specific conductance, dissolved oxygen, turbidity, and oxidation-reduction potential) will be measured during purging and immediately before sample collection during volume purge groundwater sampling. Field parameters will be measured in accordance with HMC's sampling protocol. The type of electrodes used for the field parameter measurements will be recorded in the field log book. Ferrous iron will be determined in the field using Hach test kits.

3.3.3 Groundwater Analyses

Groundwater will be collected, preserved as appropriate, and sent to Energy Laboratories, Inc., unless otherwise noted. Samples will be analyzed for:

- Total metals via USEPA Method 6020 for aluminum, calcium, iron, potassium, magnesium, manganese, molybdenum, sodium, selenium, uranium, and vanadium; sample will be unfiltered and preserved with nitric acid.
- Dissolved metals via USEPA Method 6020 for aluminum, calcium, iron, potassium, magnesium, manganese, molybdenum, sodium, selenium, uranium, and vanadium; sample will be field filtered to 0.45 micron and preserved with nitric acid.
- Alkalinity via Standard Method (SM) 2320
- Major anions, including sulfate and chloride (USEPA Method 300.0), and nitrate/nitrite (SM 4500)
- Uranium isotopes (U-234, U-235, and U-238)
- Sulfur stable isotopes through IT2 Laboratories.
- Total organic carbon and dissolved organic carbon (after filtration through a 0.45 µm filter) by SM5310C
- Phosphate-phosphorus by USEPA Method 365.1

4 QUALITY ASSURANCE AND QUALITY CONTROL

4.1 Field Documentation and Sample Labeling

Daily activities will be recorded in a dedicated field notebook. Field books will be completed in accordance with the procedures outlined in the SOP for Field Log Book Entries (**Appendix C**). Sampling logs and collection forms will be used to document site and sample data as detailed above.

Each analytical sample will be given a unique alphanumeric identifier as defined in **Table 5**.

4.2 Field Quality Assurance and Quality Control

Sample collection and handling and laboratory analyses will be conducted in accordance with the QAPP (**Appendix A**). Field QA/QC is dependent on proper equipment calibration, decontamination, and care by field workers to adhere to SOPs and field protocols. Critical components of the field QA/QC process include documenting field activities, cross-checking sample labels, chain-of-custody forms, and field documents, and completing daily activity logs. Additional checks on field QA/QC include collection of field duplicates, equipment blank samples (where appropriate), field blank samples (where appropriate), and matrix spike (MS)/matrix spike duplicate (MSD) samples, where appropriate. **Table 6** provides the frequency at which field QA/QC samples will be collected.

- Field duplicate samples are collected to measure the sampling and analytical variability associated with the sample results. Duplicate samples are usually collected simultaneously with or immediately after the corresponding original samples have been collected. The same sampling protocol is used to collect the original sample and the field duplicate sample. The field duplicate is analyzed for the same suite of analytical parameters as the original sample. Field duplicates will be collected at a rate of one per 20 samples, in accordance with the Contract Laboratory Program National Functional Guidelines for Inorganic Review (USEPA 2014).
- Equipment blanks will not be collected for soil samples because the soil will be accessed directly using single-use, sterile, disposable scoops and placed directly into a laboratory-supplied sample container.
- An MS/MSD is a double-volume sample used by the laboratory to evaluate whether matrix effects are interfering with sample analyses and, therefore, compromising the accuracy or precision of those analyses. MS/MSD samples will be collected at a frequency of one per 20 samples (USEPA 2014). Additional sample containers for MS/MSD sample analyses will be labeled using the same sample identification as the parent sample.

Field QA/QC sample descriptions, collection procedures, and collection frequencies are summarized in **Table 6**.

4.3 Investigation-Derived Waste

It is anticipated that three main types of investigation-derived waste (IDW) may be created as a result of field activities: drilling boreholes, pump/purge water generated as a result of groundwater well development, and routine disposal of personal protective equipment (PPE). IDW drill cuttings generated during borehole drilling and IDW water from well pump/purging will be disposed of on site as directed by HMC. PPE will be disposed of on site as municipal solid waste.

4.4 Additional Sampling Events

If HMC intends to conduct any additional sampling events following the activities described in this SAP, Arcadis will prepare a technical addendum to this SAP that outlines the locations and analyses that will be part of the additional sampling events.

5 HEALTH AND SAFETY

HMC and Arcadis place the highest priority on the safe and environmentally responsible conduct of the work and follow the “every person going home safe and healthy every day” mentality. As such, HMC has outlined specific health and safety compliance guidance for all site workers. Site activities will follow all HMC health and safety compliance requirements including, but not limited to:

- HMC Grants Reclamation Project specific contractor requirements
- As Low As Reasonably Achievable (ALARA) training as required by HMC prior to site entry
- Radiation Awareness training in accordance with HMC and Arcadis standards.

Arcadis has created a site-specific Health and Safety Plan (HASP) to outline safety expectations and provide guidance for safe work practices for all field activities. The HASP outlines a site-specific hazard analysis and mitigation, monitoring plan, and training requirements that follow both HMC and Arcadis safety policies. The HASP is required reading for personnel conducting field activities at the Site.

Prior to commencing work each day, the Daily Health and Safety Plan Tailgate Meeting Form must be completed and maintained in the project files and/or electronic directory. The date and general content of a daily morning health and safety meeting will be recorded on Daily Logs.

6 REFERENCES

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SAP
TABLES

Table 1
Soil Analysis Goals
2019 Background Investigation
Grants Reclamation Project

Analyte	Method	Supporting Detail and Analysis Goal
Total metals in soil[a] *(environmentally accessible)*	USEPA 3050B with 6020Bb	Analysis of total metals in soil is necessary to provide an understanding of the geochemical behavior of constituents of concern in the alluvial aquifer and alluvial sediments. This analysis will provide the concentration of environmentally accessible major and trace elements.
Selective Sequential Extraction[b]	Custom per Tessier et al. 1979	Selective sequential extraction uses chemical reagents that selectively dissolve individual phases or mineral forms of the target element under investigation, in this case uranium. The reagents range in chemical strength and are progressively stronger in terms of their ability to dissolve mineral phases. The results of this analysis will provide an indication of the leachability of each element based on the phase within which it predominantly resides.
Total Organic Carbon	LECO Induction Furnace	This analysis will provide an understanding of the association of uranium with organic carbon and will be performed on a subset of samples that show the highest uranium concentrations. Prior work on soils has shown the presence of particulate organic carbon.
Total Sulfur Content	LECO Induction Furnace	This analysis will provide an understanding of the association of uranium with sulfur and will be performed on a subset of samples that show the highest uranium concentrations. Prior work on soils has shown the presence of sulfide minerals.
Precise mineralogy	Petrographic microscopy	Petrographic analysis via light and polarized light microscopy has the capability to produce a definitive mineralogic assessment of alluvial aquifer sediments, including identification of small mineral grains, which cannot be resolved through x-ray diffraction.
Bulk mineralogy	XRD - scan and search	X-ray diffraction analysis can generate positive identification of a wide variety of mineral constituents in a sample. In contrast to petrographic and SEM-EDX analyses, which require manual microscopic exploration and targeted identification, XRD is most valuable as a bulk assessment of mineralogy and yields essential data about mineralogic variability throughout the alluvial aquifer. Based on previous characterization of uranium in the San Mateo Valley alluvial system, the majority of the uranium is expected to be encountered in coarse-grained sands and possibily silts; thus, the "scan and search" XRD method is expected to be sufficient. However, if samples that show the highest uranium are predominantly clay, a directed clay XRD analysis must be used instead.
Sulfur stable isotopes in soil[c]	Stable sulfur isotopes as analyzed by Isotope Tracer Technologies (IT^2), Waterloo, Ontario, Canada	Sulfur stable isotopes related to solid sulfates and sulfides and to sulfate in groundwater give an indication of the origin of sediments and groundwater that is difficult to achieve through other methods. Sulfur that is more highly depleted in the heavier sulfur isotopes (e.g., sulfur-34) has most likely been through the microbial sulfate reduction process. This process can only occur when a system is significantly reducing and, as a result, represents an environment where uranium reduction, precipitation, and concentration could occur.
Mineralogy and elemental composition	QEMSCAN	QEMSCAN is a rastering scanning electron microscope technique with four Energy Dispersive Spectrometers that uses proprietary software to map the mineral distribution across a sample surface. QEMSCAN can identify areas in a sample that contain concentrated uranium and on which higher resolution analysis can be conducted. QEMSCAN increases the probability of encountering uranium in environmental samples over traditional non-rastering scanning electron microscopy.

Notes:

[a] Will be analyzed for aluminum, calcium, iron, magnesium, manganese, molybdenum, potassium, selenium, sodium, sulfur, uranium, and vanadium.

[b] Will be analyzed for aluminum, calcium, iron, magnesium, manganese, molybdenum, potassium, selenium, sodium, sulfur, uranium, and vanadium plus silicon (often reported as silica).

[c] Conducted at Isotope Tracer Technologies, Inc. (IT^2)

USEPA = United States Environmental Protection Agency

QEMSCAN = Quantitative Evaluation of Materials by SCANning electron microscopy

SEM = scanning electron microscopy

XRD = x-ray diffraction

Table 2
Soil Sampling Program
2019 Background Investigation
Grants Reclamation Project

ARCADIS Design & Consultancy for natural and built assets

Laboratory	Energy Laboratories, Incorporated (ELI)			Huffman-Hazen Labs	ACZ Laboratories	DCM through ELI[c,d]	IT^2
Analysis	Environmentally accessible metals in sediment[b]	Total Organic Carbon	Total sulfur content	Mineralogy and elemental composition	Total metals by mineralogical fraction[b]	Precise mineralogy	Stable sulfur isotopes
Method[a]	USEPA 3050B with 6020B[b]	LECO Induction Furnace	LECO Induction Furnace	QEMSCAN[e]	Selective Sequential Extraction based on Tessier et al. 1979 (Table 4) with 6020B[b]	Petrographic analysis	Stable sulfur isotopes as analyzed by Isotope Tracer Technologies (IT^2), Waterloo, Ontario, Canada
Number of samples	Up to 10 samples each initial boring	Up to 15 samples	Up to 15 samples	Up to 2 samples	Up to 30 samples	Up to 8 samples	Up to 8 samples
Sample container per each sample	1 4-ounce glass jar				1 4-ounce glass jar	1 small whirl-top or zip-top plastic bag	1 4-ounce glass jar
Well/Location ID	Samples collected in the field per borehole						
BK1-C	10 samples	Up to 5 samples	Up to 5 samples	1 sample	Up to 10 samples	Up to 3 samples	Up to 3 samples
BK2-C	10 samples	Up to 5 samples	Up to 5 samples	--	Up to 10 samples	Up to 2 samples	Up to 2 samples
BK1-F	--	--	--	--	--	--	--
BK2-F	--	--	--	--	--	--	--
BK3	10 samples	Up to 5 samples	Up to 5 samples	1 sample			
DUP	One sample	One sample	One sample	--	Up to 10 samples	Up to 3 samples	Up to 3 samples
MS/MSD	One sample	One sample	One sample	--	--	--	--

Notes:

[a] Specific methods are subject to change based on the laboratory capabilities at the time of sample submittal.

[b] Will be analyzed for aluminum, calcium, iron, magnesium, manganese, molybdenum, potassium, selenium, silicon, sodium, uranium, and vanadium.

[c] DCM will be subcontracted through ELI.

[d] Microscopy samples will be collected, homogenized in their sample container, packaged in the field, and sent to ELI; all microscopy samples will be retained by ELI until Arcadis reviews data from the total metals analysis. Arcadis will subsequently select up to 5 microscopy samples to be shipped by ELI to DCM for analysis.

[e] Analytical techniques are being identified that can detect uranium at the low concentrations that occur in these samples; a different type of analysis may be substituted for QEMSCAN if it is determined to be more appropriate for this task.

[f] Ten splits from the density fractional separation of five field samples conducted by Hazen Laboratories will be sent to ELI for analysis of aluminium, calcium, iron, magnesium, manganese, molybdenum, potassium, selenium, silicon, sodium, uranium, and vanadium.

-- = no sample to be collected
ACZ = ACZ Laboratories in Steamboat Springs, Colorado
DCM = DCM Science Laboratory, Incorporated in Wheat Ridge, Colorado
DUP = duplicate measurement/sample
ELI = Energy Laboratories, Incorporated in Casper, Wyoming
BK1-C = borehole installed at location 1 that will be screened in coarse sediments when converted to a well
BK1-F = borehole installed at location 1 that will be screened in fine sediments when converted to a well
BK2-C = borehole installed at location 2 that will be screened in coarse sediments when converted to a well
BK2-F = borehole installed at location 2 that will be screened in fine sediments when converted to a well
MS/MSD = matrix spike/matrix spike duplicate; MS/MSD samples do not require a separate sample ID; samples intended for MS/MSD analysis should be indicated in the comment section of the Chain of Custody form.
QEMSCAN = Quantitative Evaluation of Materials by SCANning electron microscopy
USEPA = United States Environmental Protection Agency
XRD = x-ray diffraction

Table 3
Analytical Methods, Preservation, and Holding Times
2019 Background Investigation
Grants Reclamation Project

Laboratory Measurement or Task	Matrix	Preservation	Sample Volume or Containers	Holding Times	Analytical Method[a]	Special Handling
Energy Laboratories, Inc.						
pH and ORP on soil	solid	4 ± 2°C	One 4-Ounce glass jar	20 days	ASA10-3 (pH) and A2590BM (ORP)	--
Environmentally accesible metals in solids[b]	solid	4 ± 2°C	One 4-Ounce glass jar	180 days	EPA 3050B/6020B	--
Total metals by particle size[b]	solid	4 ± 2°C	Samples as prepared by Huffman Hazen Laboratories (HHL)	179 days from the date of collection	EPA 3050B/6020B	Samples sent from HHL to ELI
Total Organic Carbon	solid	4 ± 2°C	One 1-Quart plastic zip-top bag	30 days	LECO Induction Furnace	--
Total sulfur	solid	4 ± 2°C		30 days	LECO Induction Furnace	--
Total metals[b]	water	HNO_3 to pH<2; 4 ± 2°C	250 mL plastic, nonfiltered	6 months	EPA 6020	--
Dissolved metals[b]	water	HNO_3 to pH<2; 4 ± 2°C	250 mL plastic, filtered	6 months	EPA 6020	--
Alkalinity as $CaCO_3$	water	4 ± 2°C	One 1-Liter plastic, nonfiltered	14 days	SM 2320B	--
Major Anions[c]	water	4 ± 2°C	One 1-Liter plastic, nonfiltered	28 days	EPA 300.0	--
Nitrate as N	water	H_2SO_4 to pH <2; 4 ± 2°C	250 mL plastic, nonfiltered	28 days	SM 4500	--
Ammonia as N	water	H_2SO_4 to pH <2; 4 ± 2°C	250 mL plastic, nonfiltered	28 days	SM 4500	--
Uranium-234, -235,-238	water	HNO_3 to pH<2; 4 ± 2°C	Two 1-Liter plastic, nonfiltered	180 days	EPA 908.0	--
IT^2 Laboratories						
Sulfur stable isotopes	water	none	One 1-Liter plastic, nonfiltered	none specified	Stable sulfur isotopes as analyzed by Isotope Tracer Technologies (IT2), Waterloo, Ontario, Canada	Provide sulfate and chloride results for parent samples when available, needed before analysis is performed. Volume must contain 10 mg sulfate, high chloride samples must contain 20 mg sulfate.
Sulfur stable isotopes	solid	none	200 grams	none specified		--
Huffman Hazen Laboratories (HHL)						
Mineralogical identification via QEMSCAN	solid	none		none specified	QEMSCAN	--
DCM Laboratory, Inc.						
Prepare thin sections	solid	none	1 small whirl-top or zip-top plastic bag for all analyses	none specified	DCM SOP	--
Petrographic analysis	solid	none		none specified	DCM SOP	--
X-ray diffraction	solid	none		none specified	DCM SOP	--
ACZ Laboratories, Inc.						
Selective sequential extraction (SSE)	solid	none	40 grams of material in whirl-top or zip-top plastic bag	none specified	SSE (Table 4), EPA 3050B/6020B	--

Notes:

-- = not applicable/required

[a] Specific methods are subject to change based on the laboratory capabilities at the time of sample submittal

[b] Will be analyzed for aluminum, calcium, iron, magnesium, manganese, molybdenum, potassium, selenium, silicon, sodium, uranium, vanadium

[c] Must include chloride, fluoride, sulfate

< = less than

°C = degrees Celsius

ACZ = ACZ Laboratories, Inc.

ASTM = ASTM International

$CaCO_3$ = calcium carbonate

DCM = DCM Science Laboratory, Inc.

EPA = United States Environmental Protection Agency

HNO_3 = nitric acid

H_2SO_4 = sulfuric acid

H_3PO_4 = phosphoric acid

mL = milliliter

QEMSCAN = Quantitative Evaluation of Materials by SCANning electron microscopy

SEM-EDS = scanning electron microscopy with energy dispersive x-ray spectroscopy

SM = Standard Method

SOP = standard operating procedure

SSE = selective sequential extraction

XRD = x-ray diffraction

Table 4
Selective Sequential Extraction Protocol
2019 Background Investigation
Grants Reclamation Project

Extraction Step	Description	Reagent	Procedure
I	Water Soluble	Distilled water	1. Prepare sample by drying at 105 °C and grinding in agate mortar.
			2. Weigh 2.0 grams of soil into 50 mL centrifuge tube.
			3. Add 30 mL deionized H_2O.
			4. Shake for 1 hour.
			5. Centrifuge at 12,000 g for 30 minutes.
			6. Pipette supernatant into plastic syringe and filter through 0.45 µm pore-size syringe filter.
			7. Analyze supernatant for U, V, Se, Mo, Ca, Mg, Na, Al, Fe, Mn, Si, sulfate, carbonate, phosphate
II	Adsorbed	0.0144M $NaHCO_3$ / 0.0028 M Na_2CO_3	1. Add 16 mL of 0.0144 M NaHCO3 / 0.0028 M Na_2CO_3 solution.
			2. Shake for 1 hr.
			3. Centrifuge @ 12,000 g for 30 minutes.
			4. Pipette supernatant into plastic syringe and filter through 0.45 µm pore-size syringe filter.
			5. Analyze supernatant for U, V, Se, Mo, Ca, Mg, Na, K, Al, Fe, Mn, Si, sulfate, phosphate
			6. Add 16 mL deionized H2O into centrifuge tube containing the solid sample and hand shake for 1 minute.
			7. Centrifuge @ 12,000 g for 30 minutes.
			8. Pipette and discard supernatant.
III	Carbonate Bound	1 M NaOAc (pH = 5.0)	1. Add 16 mL of 1 M NaOAc (adjusted to pH = 5 with HOAc).
			2. Shake for 2.5 hour.
			3. Repeat steps 3 through 8 in Extraction Step II.
IV	Oxide Bound	0.04 M $NH_2OH \cdot HCl$ in 25% (v/v) HOAc	1. Add 40 mL of 0.04 M $NH_2OH \cdot HCl$ in 25% (v/v) HOAc (pH ≈ 2).
			2. Hand shake for 1 minute.
			3. Place in oven at 96 ± 3 °C for 6 hours. Hand shake every 1 hour.
			4. After 6 hours, remove from oven and hand shake.
			5. Repeat steps 3 through 8 in Extraction Step II.
V	Organic Bound	0.02 M HNO_3 / 3.2 M NH_4OAc	1. Add 6 mL of 0.02 M HNO_3.
			2. Add 10 mL of 30% H_2O_2 adjusted to pH = 2 with HNO_3.
			3. Hand shake for 1 minute.
			4. Place into oven at 85 ± 2 °C for 2 hours.
			5. Hand shake for 1 minute after 1 hour and 2 hours.
			6. Add 6 mL H_2O_2 (pH = 2 with HNO_3) and hand shake for 1 minute.
			7. Heat to 85 ± 2 °C for 3 hours. Shake for 1 minute each hour.
			8. Allow sample to cool to room temperature.
			9. Add 10 mL of 3.2 M NH_4OAc in 20% (v/v) HNO_3.
			10. Add 8 mL deionized H_2O.
			11. Shake for 30 minutes.
			12. Repeat steps 3 through 8 in Extraction Step II.
VI	Residual	HF/HNO_3	1. Digest final residue using EPA Method 3052.
			2. Analyze digest for U, V, Se, Mo, Ca, Mg, Na, Al, Fe, Mn, Si.

Notes:

Protocol from Tessier et al. 1979.
% - percent
µm - micrometer
°C - degrees Celsius
g - times gravity force
M - molar
mL - milliliter
v/v - by volume

Table 5
Sample Designation System
2019 Background Investigation
Grants Reclamation Project

First Field	Second Field	Third Field
Soil Samples		
Example: *BK1-C-1-2-012319* is a sample collected at borehole GF1-CS, from 1-2 feet below ground surface on January 23, 2019.		
Location	Depth	Date
Location ID as defined in Table 2	Sample depth range in feet below ground surface (e.g., minimum depth - maximum depth)	6-digit date code: mmddyy
Groundwater Samples		
Example: *BK1-C-012319* is a sample collected at monitoring well GF1-CS on January 23, 2019.		
Location	Date	--
Location ID as defined in Table 2	6-digit date code: mmddyy	--
Field Quality Control Samples		
Examples: *DUP-01* is the first duplicate sample to be collected during a sampling event; parent sample shall be recorded on field sampling forms and/or in the field notebook.		
Location ID	Duplicate number	--
For duplicates, "DUP" in place of boring ID	A number 01 through 100, not to be repeated in the same sampling event for the same sample type	--
For equipment blank, "EB" in place of boring ID	A number 01 through 100, not to be repeated in the same sampling event for the same sample type	--
For field blank, "FB" in place of boring ID	A number 01 through 100, not to be repeated in the same sampling event for the same sample type	--

Notes:
Matrix spike/matrix spike duplicate (MS/MSD) samples do not require a separate sample ID; samples intended for MS/MSD analysis should be indicated in the comment section of the chain-of-custody form.
-- = not applicable

DUP = duplicate
EB = equipment blank
FB = field blank
ID = identification

Table 6
Field Quality Control Samples and Frequencies
2019 Background Investigation
Grants Reclamation Project

Field Quality Control Sample Type	Description/Collection	Collection Frequency	Sample Analysis
Field Duplicate	Duplicate samples will be collected by filling two laboratory-supplied bottle sets at the same sampling location at the same time.	1 per 20 primary samples	Duplicate samples will be analyzed for each constituent analyzed for in the parent sample via select methods.[a]
MS/MSD	Double volume samples (two bottle sets) will be collected and submitted to the laboratory for MS/MSD.	1 per 20 primary samples	MS/MSD will be analyzed for each constituent analyzed for in the parent sample via select methods.[a]

Notes:

Field and/or equipment blanks may be collected according to Homestake Mining Company's groundwater sampling protocols.

[a] Duplicates and MS/MSDs will be analyzed/conducted for Total metals via USEPA Methods 3050B/6020B and total organic carbon and total sulfur via the LECO Induction Furnace method

USEPA = United States Environmental Protection Agency

MS/MSD = matrix spike/matrix spike duplicate

SAP FIGURES

CITY: (DENTECH) DIV/GROUP:(ENV) DB:KKELLEY LD: PIC: PM: TM: DATE: 2/11/2019
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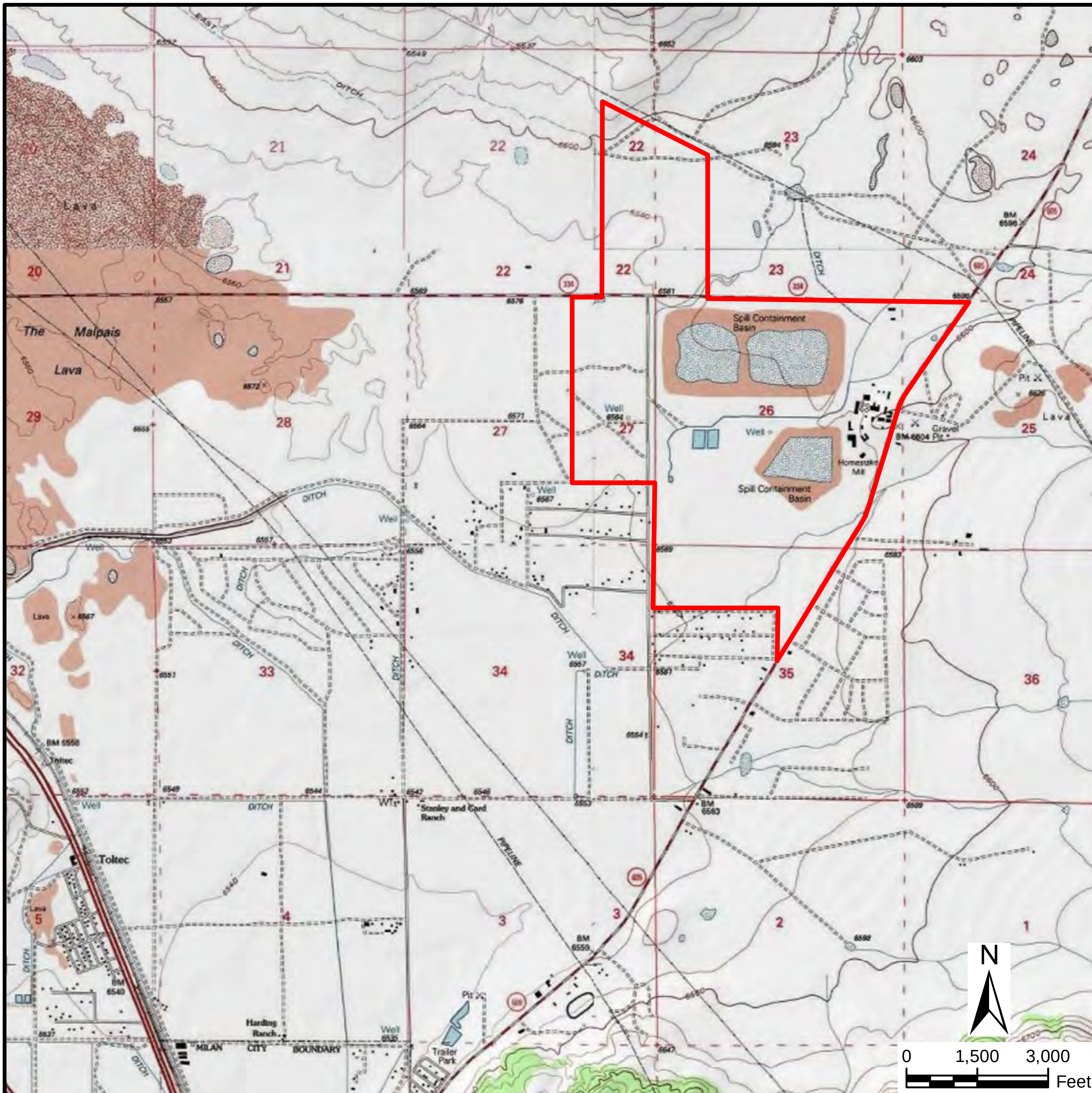
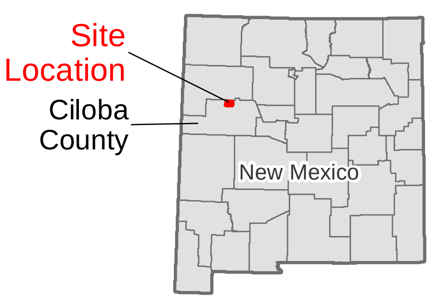


Source: USA Topo Maps, serviced by ESRI ArcGIS Online

LEGEND:

Nuclear Regulatory Commission License Boundary



SAMPLING AND ANALYSIS PLAN
2019 BACKGROUND INVESTIGATION
GRANTS RECLAMATION PROJECT

SITE LOCATION MAP

ARCADIS

FIGURE
1

CITY: (DENTECH) DIV/GROUP:(ENV) DB:KKELLEY LD: PIC: PM: TM: DATE: 5/14/2019
PROJECT: PATH: Z:\GISProjects_ENV\AO000120-Grants\GIS\ArcMaps\2019\Background_Investigation_Work_Plan\Fig_2_Approximate_Locations_of_Planned_Activities.mxd

LEGEND

- Existing alluvial aquifer wells planned for downhole geophysical logging including natural gamma, spectral gamma, and induction conductivity (see Note 1)
- New Borehole Locations
- Alluvial Borehole
- Fault
- Proposed Electrical Resistivity Line
- DD-BK 2018 Borehole Location

Subcrop* of Upper Chinle Alluvium Overlies Sandstone
- Saturated Alluvium

Subcrop* of Middle Chinle Alluvium Overlies Sandstone
- Saturated Alluvium
- Unsaturated Alluvium

* Subcrop boundary dashed where inferred.

Notes:
1) Only spectral gamma data will be collected for wells DD, DD2, MV, ND, and Q.
2) Four new borehole locations will be advanced along the resistivity lines; the locations shown on this map are based upon completion of the ERT survey.
3) Four new wells (at locations BK1 and BK2) will undergo downhole geophysical assessment via natural gamma, spectral gamma, and induction conductivity, boreholes BK3 and BK4 will also undergo geophysical assessment.

N

0 2,000 4,000
SCALE IN FEET

Basemap features from:
Hydro-Engineering, LLC, 2011

SAMPLING AND ANALYSIS PLAN
2019 BACKGROUND INVESTIGATION
GRANTS RECLAMATION PROJECT

APPROXIMATE LOCATIONS OF PLANNED ACTIVITIES

ARCADIS

FIGURE
2

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

SAP
APPENDIX A
Quality Assurance Project Plan

ARCADIS Design & Consultancy for natural and built assets

HOMESTAKE

Homestake Mining Company of California

QUALITY ASSURANCE PROJECT PLAN: 2019 BACKGROUND INVESTIGATION

Grants Reclamation Project
Grants, New Mexico

May 2019, Revision: 1

QUALITY ASSURANCE PROJECT PLAN: 2019 BAGKGROUND INVESTIGATION

Grants Reclamation Project
Grants, New Mexico

Prepared for:
Homestake Mining Company of California

Prepared by:
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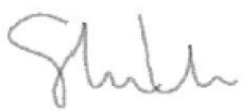
Our Ref.:
CO000120.1901

Date:
May 2019

Revision: 1

Jennifer Singer
Quality Assurance Manager



Shannon Ulrich
Technical Lead

VERSION CONTROL

Issue	Revision No	Date Issued	Page No	Description	Reviewed by
	1	5-13-19	All	QAPP signed, draft removed	JG

CONTENTS

EXHIBIT

ACRONYMS AND ABBREVIATIONS

ACZ	ACZ Laboratories, Inc.
Arcadis	Arcadis U.S., Inc.
CDPHE	Colorado Department of Public Health and Environment
CLP	Contract Laboratory Program
COC	chain-of-custody
CSM	conceptual site model
DCM	DCM Science Laboratory
DQO	data quality objective
EDD	electronic data deliverable
ELI	Energy Laboratories, Inc.
EQuIS	Environmental Quality Information System
ERT	electrical resistivity tomography
GRP	Grants Reclamation Project
GWPS	Groundwater Protection Standard
Hazen	Huffman Hazen Laboratories
HMC	Homestake Mining Company of California
ID	identification
IT^2	Isotope Tracer Technologies, Inc.
LCS	laboratory control sample
LTP	large tailing pile
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
NIST	National Institute of Standards and Technology
NMED	New Mexico Environmental Department
NRC	Nuclear Regulatory Commission
QA	quality assurance
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan

QC	quality control
RL	reporting limit
RPD	relative percent difference
SAP	Sampling and Analysis Plan: 2019 Background Investigation
SDG	sample delivery group
Site	Grants Reclamation Project located in Grants, New Mexico
SOP	Standard Operating Procedure
USGS	U.S. Geological Survey
USEPA	United States Environmental Protection Agency

1 INTRODUCTION

This Quality Assurance Project Plan (QAPP) provides quality assurance/quality control (QA/QC) procedures associated with the 2019 Background Investigation as described in the associated Sampling and Analysis Plan (SAP) prepared for the Homestake Mining Company of California (HMC) Grants Reclamation Project (GRP) located in Grants, New Mexico (Site). Arcadis U.S., Inc. (Arcadis) prepared this QAPP on behalf of HMC. This QAPP describes the policies and procedures for ensuring that work processes and products satisfy stated expectations or specifications.

The field activities covered in the SAP include an electrical resistivity tomography (ERT) assessment, downhole geophysical characterization in several existing monitoring wells, installation of two boreholes to conduct lithologic logging, soil sampling and correlated geophysical characterization of lithologies within the borings, and analysis of results from groundwater sampling performed by HMC.

This QAPP is intended to guide field sampling and field and laboratory measurement activities conducted as part of the work performed by Arcadis in accordance with the SAP. To the extent that other work plans are written and approved relevant to this QAPP, those work plans will build on and refer to the information provided in this QAPP to document a complete QA program.

1.1 Objectives

The objective of this QAPP is to document the data quality specifications and methods that will be used to establish technical accuracy and precision, statistical validity, and documentary evidence of environmental data generated during field activities conducted at the Site.

1.2 Distribution and Revision

This QAPP is a controlled document. Controlled distribution will be implemented to ensure that only the most current approved version is used. A sequential revision numbering system will be in place to identify changes in the controlled versions of this QAPP. Versions will be provided to managers, QA coordinators, field personnel, and subcontractor representatives, if applicable.

Addenda, updates, or revisions to this QAPP may be prepared if guidelines, procedures, regulatory documents are revised, or if project objectives, scope, or site activities change.

2 PROJECT MANAGEMENT

The activities to be completed under the SAP will require integration of personnel from the following organizations, identified in the project team organization chart presented below in Exhibit 1, collectively referred to as the “project team”:

- Regulatory Agencies
  - Nuclear Regulatory Commission (NRC)
  - United States Environmental Protection Agency (USEPA)
  - New Mexico Environmental Department (NMED)
- HMC
- Arcadis
- Laboratories
  - Energy Laboratories, Inc. in Casper, Wyoming (ELI)
  - DCM Science Laboratory in Wheat Ridge, Colorado (DCM), subcontracted through ELI
  - ACZ Laboratories, Inc. in Steamboat Springs, Colorado (ACZ)
  - Huffman Hazen Laboratories in Golden, Colorado (Hazen)
  - Isotope Tracer Technologies, Inc. in Waterloo, Ontario (IT2)

The primary end data users for the project who will be provided copies of this QAPP, as indicated in the organization chart, include HMC and its consultants, contractors and subcontractors, and the analytical laboratories, as well as the appropriate regulatory agencies as determined by the HMC Project Manager (PM).

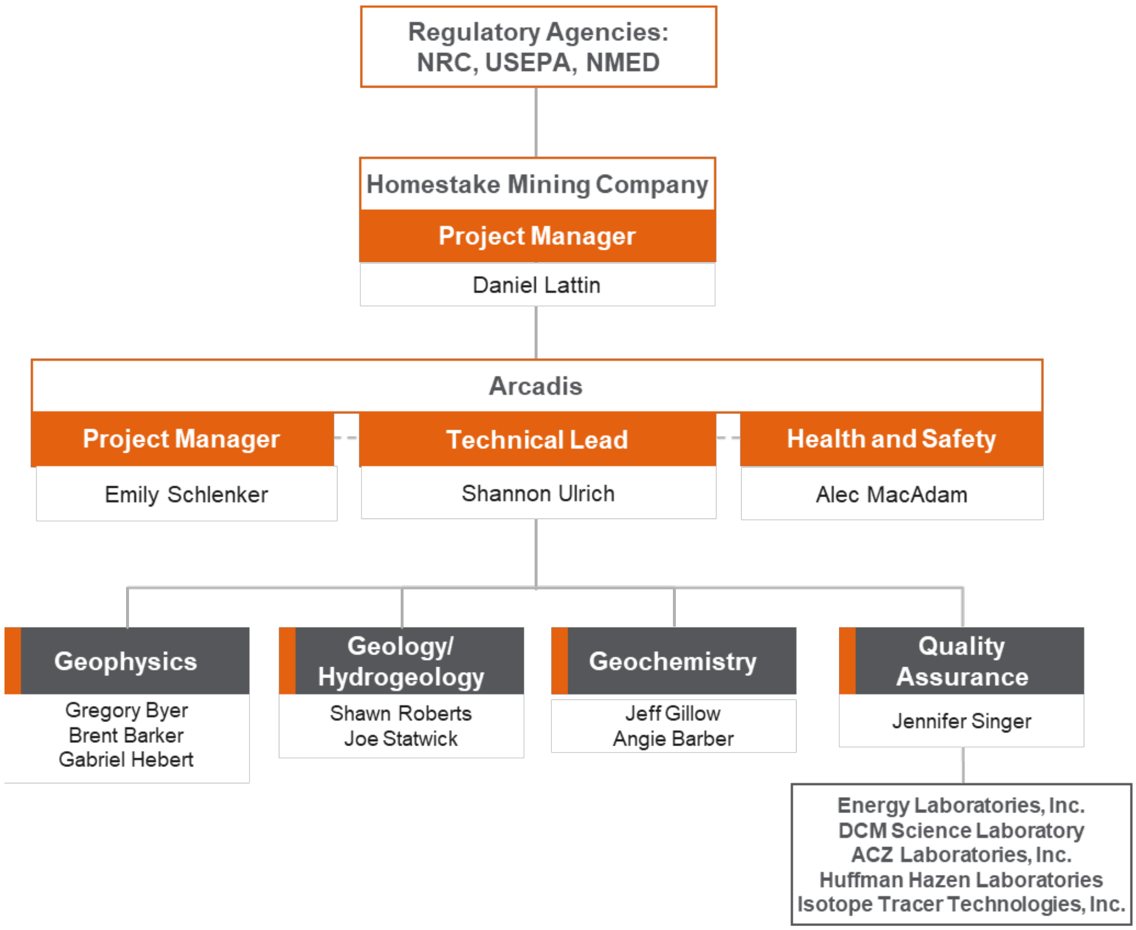


Exhibit 1. Project team organization chart.

3 PROJECT DATA QUALITY OBJECTIVES

Data Quality Objectives (DQOs) were developed in accordance with the USEPA's 7-step DQO Process presented in Guidance on Systematic Planning Using the Data Quality Objectives Process, USEPA QA/G-4, EPA/240/B-06/001, February 2006 (USEPA 2006). As described in this guidance, the DQO process is used to develop performance and acceptance criteria (or DQOs) that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. The DQO process identifies the problem, the goal of the study, the information inputs, the boundaries of the study, the analytical approach, performance and acceptance criteria, and the plan for obtaining data, as follows:

Step 1: State the Problem
Stakeholder groups have requested a better understanding of site-specific background water quality standards and the occurrence of uranium in the alluvial system at the GRP. In 2016, the USEPA, with the assistance of the United States Geological Service (USGS), initiated a reassessment of site background water quality standards and included well reconnaissance, geophysics, and sampling of groundwater via micropurge, volume purge, and passive sampling techniques. Arcadis was engaged by HMC to collect split samples with the USGS during the 2016 sampling events. Arcadis' interpretation of data collected during split sampling and a subsequent soil investigation is that groundwater uranium concentrations in near-upgradient alluvial wells are attributed to locally naturally-occurring uranium in soils. Arcadis prepared a detailed report (Arcadis 2018a) that is included as an appendix in a white paper (Arcadis 2018b) documenting this conceptual site model (CSM). The white paper was provided to USEPA and NMED and the findings were discussed in subsequent meetings between the USEPA, NMED, HMC, NRC, and Arcadis. In order to address technical inquiries from the USEPA and NMED relating to the CSM, a supplemental background investigation is necessary.
Step 2: Identify the Goal of the Study
The primary goal of the supplemental background investigation at the GRP is to refine the CSM for natural uranium distribution and transport by identifying the lithological and hydraulic conductivity heterogeneity as well as the local variation in uranium concentrations across the alluvial channel upgradient (north) of the large tailing pile (LTP).
Step 3: Identify Information Inputs
The data needed to accomplish the goals of the supplemental background investigation are as follows: • Lithology and stratigraphy of the alluvial channel north of the LTP, including visualization of channel geometry and high-permeability zones containing coarse-grained materials; • In-situ alluvium concentrations of uranium, thorium, and potassium to 1) identify relationships between naturally occurring uranium and litho-stratigraphic conditions, mineralogies, and geochemical parameters and 2) interpretation of the provenance of the alluvial sediments using the thorium-potassium ratios;

• Mineralogical and geochemical data as well as uranium and other element concentrations from both fine-grained and coarse-grained sediments; and • Temporal trends in geochemical data and uranium concentrations in groundwater associated with (i.e., separately screened across) fine-grained and coarse-grained sediments.
Step 4: Define the Boundaries of the Study
Geophysical, lithological, and sampling activities to obtain the data needed to support the goals of the supplemental background investigation will include new boreholes and wells located along a cross-section across the alluvial channel as well as existing alluvial aquifer wells north of the LTP at the GRP.
Step 5: Develop the Analytical Approach
Geophysical assessments include an ERT assessment and downhole geophysical logging. • ERT assessment data will be used to inform the drilling phase of the program as well as to map the alluvial channel geometry and high-permeability zones. • Downhole geophysical logging of existing and new boreholes/wells will provide a common set of detailed, quantitative, in-situ measurements to link interpretations between visual geologic descriptions, lithology of alluvial material surrounding existing monitoring wells where visual descriptions may be unavailable or of low detail, and the large-scale ERT cross-sections. Lithological assessment and installation of two groundwater wells will be conducted at two different locations along the ERT transects. • Soil sampling during advancement of the boreholes will provide geochemical data from both fine-grained and coarse-grained sediments. • The groundwater monitoring wells will be installed with short screen intervals separately screened across the fine-grained and coarse-grained sediments to assess the associated geochemical trends in groundwater. The results will be used to refine the CSM. • Groundwater data reflecting that higher uranium concentrations are associated with the finer-grained sediments would indicate that uranium was naturally emplaced during fluvial deposition and is being released into groundwater locally by natural processes. • Conversely groundwater data reflecting that higher uranium concentrations are associated with the coarser-grained, high hydraulic conductivity sediments could suggest that uranium in groundwater may be present because of regional groundwater sources.
Step 6: Specify Performance or Acceptance Criteria
Measurement performance criteria are specified in Section 10.3 of this QAPP. Groundwater data will be compared to the Site Groundwater Protection Standards (GWPSs).
Step 7: Develop the Plan for Obtaining Data
This SAP presents the rationale and plan, including field and analytical methods, for obtaining geophysical, lithological, and soil and groundwater sampling data.

4 LEVELS OF DATA REPORTING

For the purposes of the assessment, three levels of data reporting are defined here. The appropriate data reporting level will be specified with each analytical laboratory request; Level 1 and Level 2 reporting will be the most common reporting type used on this project.

Level 1 – Minimal Reporting. Minimal or “results only” reporting is used for analyses that, due either to their nature (i.e., field monitoring or specialty analyses that do not follow USEPA reporting protocols such as X-ray Diffraction or stable isotope analyses) or the intended data use (i.e., preliminary screening), do not generate or require extensive supporting documentation.

Level 2 – Modified Reporting. Modified reporting is used for analyses that are performed following standard USEPA-approved methods and QA/QC protocols. Based on the intended data use, modified reporting may require some supporting documentation, but not full Contract Laboratory Program (CLP)-type reporting. Level 2 laboratory data report-required elements are method-specific and may include, but are not limited to, the following:

- COC
- Case narrative
- Final parameter concentration for all samples
- Preparation or extraction and analysis dates/times
- Method blanks
- Matrix spike (MS) and matrix spike duplicate (MSD) recoveries and relative percent difference (RPD)
- Laboratory duplicate RPD
- Laboratory control sample (LCS) recoveries
- Counting uncertainty and confidence intervals (if applicable)

Level 4 – Full Reporting: Full “CLP-type” reporting is used for those analyses that, based on the intended data use, require full documentation. Level 4 laboratory data report-required elements are method-specific. They may include some or all of the elements for Level 2 listed above and may also include, but are not limited to, the following:

- Calibrations (initial and continuing)
- Instrument blanks
- Internal standard areas
- Serial dilution %D
- Raw data output for project samples and associated QA/QC samples

5 SPECIAL TRAINING REQUIREMENTS/CERTIFICATION

Copies of training certificates and records for Arcadis personnel working onsite will be kept with Arcadis' Training Department. Arcadis employees are provided training, as necessary, for the completion of projects, as determined by Arcadis' corporate Health and Safety Officer and Education and Training Department.

6 DOCUMENTATION AND RECORDS

Documents and records are retained in the Arcadis offices, as well as at offsite storage facilities. Records accessed less frequently than once per month may be sent to storage and retrieved, as needed. Electronic documents, data, databases, and electronic communication will be stored within files and folders located on computerized hard disk servers.

7 FIELD PROCEDURES

This section details general QA/QC requirements for the field activities described in the SAP.

7.1 Field Equipment

Instruments and equipment used by Arcadis to gather, generate, or measure environmental data will be calibrated and maintained according to manufacturer specifications, and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications.

7.1.1 Maintenance and Inspection

Each piece of field equipment used by Arcadis in support of the field sampling activities that directly affect the quality of the analytical data will be subject to preventative maintenance measures that minimize equipment downtime. Equipment will be examined to ensure that it is in operating condition. When available, field notes from previous sampling events will be reviewed to ensure that any prior equipment problems are not overlooked, and that any necessary repairs to equipment have been carried out.

Prior to field sampling activities, each piece of field equipment will be inspected to ensure that it is operational. If the equipment is not operational, it will be taken out of use until it can be serviced. Meters that require charging or batteries will be fully charged, and fresh batteries will be kept on hand. If instrument servicing is required, it is the responsibility of the field personnel to follow the maintenance schedule and arrange for timely service.

7.1.2 Calibration

Field monitoring and detection equipment will be routinely calibrated according to manufacturer specifications. To demonstrate that established calibration procedures have been followed, calibration records will be prepared and maintained on the appropriate logs.

If a calibrated instrument fails to meet calibration verification, it will be removed from use until it can be serviced. Equipment found to be out of tolerance during the period of use will be removed from use, and measuring and testing activities performed using the equipment will be noted as such on the field logs.

7.2 Field Data Documentation

Field personnel will provide comprehensive documentation covering each aspect of field sampling, field analysis, and sample COC as specified in the SAP and herein. This documentation provides records of activities and allows for reconstruction of all field events to aid in the data review and interpretation process. Documents, records, and information relating to the performance of the field work will be retained in the project file.

Each page or entry of field notes will be dated and initialed by the field personnel at the time of entry. Errors in entry will be crossed out in indelible ink with a single stroke, corrected without the use of white-out or by obliterating or writing directly over the erroneous entry, and initialed and dated by the individual making the correction. Pages that are not used will be completed by lining out unused portions. To ensure at any future date that pages are not missing, each page will be sequentially numbered.

7.2.1 Field Logs

Field logs will provide the means of recording the data collection activities that are performed. As such, entries will be described in as much detail as possible so that persons going to the Site could reconstruct a particular situation without reliance on memory. Information collected in the field through visual observation, manual measurement, and/or field instrumentation will be recorded on the field logs. The specific field logs to be used are described in the SAP.

7.2.2 Field Chain-of-Custody Forms

Chain-of-custody (COC) forms are used as a means of documenting and tracking sample possession from time of collection to the time of disposal. Every field sample collected will be documented on an appropriate COC form. Field personnel will be briefed on the proper use of the COC procedure.

Completed COC forms will be required for the samples to be analyzed. COC forms will be initiated by the sampling crew in the field. The COC forms will contain the unique sample identification (ID), sample date and time, sample description, sample type, preservation (if any), and analyses required. The original COC form will accompany the samples to the laboratory. Copies of the COC form will be made prior to shipment (or multiple copy forms will be used) for field documentation. The COC forms will remain with the samples at all times. The samples and signed COC forms will remain in the possession of the sampling crew until the samples are delivered to the express carrier (e.g., FedEx), hand delivered to a permanent laboratory, or placed in secure storage.

7.3 Sample Collection Procedures

Arcadis will collect soil and/or groundwater samples as described in the SAP.

7.3.1 Sample Containers and Preservatives

The analytical laboratory will supply appropriate sample containers and preservatives, as necessary. Field personnel will be responsible for properly labeling containers and preserving samples (as appropriate). Sample labeling procedures are discussed in Section 7.3.3. Samples containers, preservation requirements, and holding times for each method are provided in Table 3 of the SAP.

7.3.2 Sample Collection Methods

Sample collection methods are described in the SAP.

7.3.3 Sample Labeling

Sample labels will be completed for each sample using waterproof ink. Completed sample labels will be affixed to each sample bottle.

The following information is required on each sample label:

- Project name
- Sample ID
- Date collected
- Time collected
- Location
- Sampler
- Analysis to be performed
- Preservative, if any

7.3.4 Sample Identification Numbers

Samples will be identified with a unique sample ID that will facilitate sample tracking. Sample IDs for primary samples and QA/QC samples are provided in Table 5 of the SAP.

Primary samples selected for MS/MSD analysis will be clearly identified on the COC notes section as MS/MSD samples and not unique samples. Double volume samples (i.e., two bottle sets) will be submitted for MS/MSD analysis.

7.3.5 Field Custody Procedures

The objective of field sample custody is to ensure that samples are not tampered or modified from the time of collection through transport and transfer to the analytical laboratory. Persons will have "custody of samples" when the samples are in their physical possession, in their view after being in their possession, or in their physical possession and secured so they cannot be tampered with. In addition, when samples are secured in a restricted area accessible only to authorized personnel, they will be deemed in the custody of such authorized personnel. Field custody documentation consists of both field logs and field COC forms.

Measures will be taken during the field investigation to prevent samples and records from being lost, damaged, or altered. When not in use, all field logs will be stored in a secure location. An electronic copy (e.g., scan to pdf) of all final field data and laboratory data will be kept in the project file.

7.3.6 Sample Handling, Packing, and Shipping Requirements

Sample packaging and shipment procedures are designed so that the samples will arrive at the laboratory, with the COC, intact.

Samples will be packaged for shipment as outlined below:

- Securely affix the sample label to the container with clear packing tape; or alternatively, clearly write the sample label information directly on the sampling container using a permanent marker.
- Check the cap on the sample container to confirm that it is properly sealed.

- Complete the COC form with the required sampling information and confirm that the recorded information matches the sample labels. NOTE: If the designated sampler relinquishes the samples to other sampling or field personnel for packing or other purposes, the sampler will complete the COC prior to this transfer. The appropriate personnel will sign and date the COC form to document the sample custody transfer.
- Wrap glass sample containers in bubble wrap or other cushioning material.
- Place 1 to 2 inches of cushioning material at the bottom of the cooler or shipping container.
- Place the sealed sample containers into the cooler or shipping container.
- If required, place ice in plastic bags, seal the bags, and place the bags loosely in the cooler.
- Fill the remaining space in the cooler with cushioning material. Samples not requiring cold shipment will be packed with sufficient material to avoid shifting and deformation during shipment.
- Place COC forms in a plastic bag and seal. Tape the forms to the inside of the cooler lid.
- Wrap strapping tape (or equivalent) around both ends of the cooler at least twice.
- Mark the cooler on the outside with the shipping address and return address, affix “Fragile” labels, and draw (or affix) arrows indicating “this side up.” Cover the labels with clear plastic tape. If the samples are being delivered directly to the laboratory or will be picked up by the laboratory’s courier service, this step is eliminated.
- Place a signed custody seal over the sample cooler lid.

Samples will be packaged by field personnel and transported as low-concentration environmental samples. The samples will be hand delivered or delivered by a commercial carrier. In some cases, the analytical method may require analysis within a shorter holding time, and arrangements will need to be made to accommodate laboratory requirements. Shipments will be accompanied by the COC form identifying the contents. The original form will accompany the shipment; copies will be retained by the sampler for the sampling office records. If the samples are sent by common carrier, either a pre-printed shipping label generated by the laboratory or a bill of lading will be used. Receipts or bills of lading will be retained as part of the permanent project documentation. Commercial carriers are not required to sign off on the COC form as long as the forms are sealed inside the sample cooler or shipping container, and the custody seals remain intact.

8 LABORATORY PROCEDURES

The following laboratories will perform the laboratory analyses. The SAP specifies which analyses will be performed by each laboratory.

Laboratory	Relevant Accreditations/Certifications
Energy Laboratories, Inc.	NMED Drinking Water, Laboratory #WY00002, effective through June 30, 2019 National Environmental Laboratory Accreditation Conference NRC Materials License 49-26846-01, effective through September 30, 2023
DCM Science Laboratory, Inc. (subcontracted by ELI)	AIHA LAP, LLC accreditation since 1986 NVLAP accreditation since 1989
ACZ Laboratories, Inc.	NMED Drinking Water Laboratory Certification Program, effective through July 31, 2019
Huffman Hazen Laboratories	USGS certified for low-levels of metals in natural waters Colorado Department of Public Health and Environment (CDPHE) certified for analytes in drinking water Certifies select Standard Reference Materials for the National Institute of Standards and Technology (NIST)
Isotope Tracer Technologies, Inc.	Not applicable

8.1 Laboratory Parameters and Methods

Samples collected by Arcadis during the 2019 field activities will be soil samples. Groundwater samples will be collected by HMC. Analytical parameters and methods, preservation requirements, and holding times are included in the SAP.

Laboratory analytical requirements presented in the subsections below include a general summary of requirements. When available, current approved USEPA methods will be used for the parameters of interest. Specialty methods will be used for non-routine analyses for which USEPA methods are not available, and these will be documented.

The primary sources for methods used in this sampling program are provided in the following documents:

- Test Methods for Evaluating Solid Waste, SW-846 Third Edition, Update 4, USEPA, December 1996.
- Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, USEPA, 1983.
- Standard Methods for the Examination of Water and Wastewater, 23rd Edition, American Water Works Association, 2017.

Additional sampling and method references provided will be documented in the project file and reported as references in data reports.

8.2 Laboratory Instruments and Equipment

Instrument calibration will follow the specifications provided by the instrument manufacturer or specific analytical method used. Records of calibrations will be filed and maintained by the laboratory.

All standards used to calibrate laboratory equipment are traceable, directly or indirectly, to the NIST; any deviation will be documented and described and approved by the laboratory QA Manager (QAM).

8.3 Laboratory Custody Procedures

8.3.1 General

Upon sample receipt, laboratory personnel will be responsible for sample custody. The original field COC form will accompany all samples requiring laboratory analysis. Samples will be kept secured in the laboratory until all stages of analysis are complete. All laboratory personnel having samples in their custody will be responsible for documenting and maintaining sample integrity.

8.3.2 Sample Receipt and Storage

Immediately upon sample receipt, the laboratory sample custodian will verify the integrity of the cooler or shipping container, integrity of the seal, open the cooler/shipping container, and compare the contents against the field COC. If a sample container is missing, a sample container is received broken, the sample is in an inappropriate container, or the sample has not been preserved by appropriate means, the Arcadis QAM will be notified. The laboratory sample custodian will be responsible for logging the samples in, assigning a unique laboratory identification number to each sample, labeling the sample bottle with the laboratory identification number, and moving the sample to an appropriate storage location to await analysis. The project name, field sample code, date sampled, date received, analysis required, storage location and date, and action for final disposition will be recorded in the laboratory tracking system. Relevant custody documentation will be placed in the project file.

8.3.3 Sample Analysis

Analysis of an acceptable sample will be initiated by a worksheet that will contain pertinent information for analysis. The routing sheet will be forwarded to the analyst, and the sample will be moved into an appropriate storage location to await analysis. The document control officer will file COC forms in the project file.

Samples will be organized into sample delivery groups (SDGs) by the laboratory (as applicable for specialty analyses). An SDG may contain up to 20 field samples (field duplicates, trip blanks, equipment blanks, and rinse blanks are considered field samples for the purposes of SDG assignment). All field samples assigned to a single SDG will be received by the laboratory on the same day and must be processed through the laboratory (preparation, analysis, and reporting) as a group. If re-analysis of a sample is required, it may be rerun separately from the original SDG; however, the resulting data will be reported with the original SDG.

Information regarding the sample, analytical procedures performed, and the results of the testing will be recorded in a laboratory notebook by the analyst. These notes will be dated and identify the analyst, instrument used, and instrument conditions.

8.3.4 Sample Storage Following Analysis

Samples will be maintained by the laboratory for at least 1 month (or as prescribed in the laboratory Standard Operating Procedure [SOP] or as requested by Arcadis for specific samples) after the final report is delivered. The laboratory will be responsible for the eventual and appropriate disposal of the samples. The analytical laboratory will inform the environmental consultant before any samples are disposed. Unused portions of the samples, sample extracts, and associated wastes will be disposed by the laboratory in accordance with applicable rules and regulations.

8.4 Laboratory Data Documentation

8.4.1 Laboratory Project Files

The laboratory will establish a file for pertinent data. The file will include correspondence, faxed information, phone logs, and COC forms. The laboratory will retain project files and data packages for a period not less than 5 years.

8.4.2 Laboratory Logbooks

Workbooks, bench sheets, instrument logbooks, and instrument printouts will be used to trace the history of samples through the analytical process and to document important aspects of the work, including the associated QC checks. As such, logbooks, bench sheets, instrument logs, and instrument printouts will be maintained by the laboratory.

Each page or entry will be dated and initialed by the analyst at the time of entry. Errors in entry will be crossed out in indelible ink with a single stroke, corrected without the use of white-out or by obliterating or writing directly over the erroneous entry, and initialed and dated by the individual making the correction. Pages of logbooks that are not used will be completed by lining out unused portions.

Information regarding the sample, analytical procedures performed, and the results of the testing will be recorded on laboratory forms or personal notebook pages by the analyst. These notes will be dated and will also identify the analyst, the instrument used, and the instrument conditions.

8.4.3 Computer and Hard Copy Storage

All electronic files and deliverables will be retained by the laboratory for not less than 5 years; hard copy data packages (or electronic copies) will also be retained for not less than 5 years.

9 DATA MANAGEMENT

The purpose of data management is to provide for the accuracy and ready accessibility of all necessary data to meet the analytical and reporting objectives of the project.

The data management program established for the project includes field documentation and sample QA/QC procedures, methods for tracking and managing the data, and a system for filing all site-related information. More specifically, data management procedures will be employed to efficiently process the information collected such that the data are readily accessible and accurate. These procedures are described in detail in the following section.

The data management plan has four elements: 1) sample designation system, 2) data collection activities, 3) sample tracking and management, and 4) data management system.

9.1 Sample Designation System

A concise and easily understandable sample designation system is an important part of project sampling activities. It provides a unique sample number that will facilitate both sample tracking and easy resampling of select locations to evaluate data gaps, if necessary. The sample designation system to be employed during the sampling activities will be consistent, yet flexible enough to accommodate unforeseen sampling events or conditions. A combination of letters and numbers will be used to yield a unique sample ID for each field sampled collected. The sample designation system is provided in Table 5 of the SAP.

9.2 Sample Tracking and Management

A record of all field documentation will be maintained to provide verification of the validity of data used in the site analysis. To effectively execute such documentation, specific sample tracking and data management procedures will be used throughout the sampling program.

Sample tracking will begin with the completion of COC forms. The completed COC forms associated with samples collected will be faxed and/or scanned and emailed to the Arcadis QAM or designee. The Arcadis QAM or designee will compare the COC forms against the sampling plan to ensure that all samples were collected and all analyses were requested. Copies of all completed COC forms will be maintained in the Arcadis office and will be provided to HMC upon request. The Arcadis QAM or designee will verify the delivery of samples using express carrier tracking numbers. The laboratory will verify receipt of the samples electronically (via email) as soon as practicable.

When analytical data are received from the laboratory, the Arcadis QAM or designee will review the incoming analytical data packages against the information on the COCs to confirm that the correct analyses were performed for each sample and that results for all samples submitted for analysis were received. Any discrepancies noted will be promptly followed up on with the laboratory by the Arcadis QAM.

9.3 Data Management System

In addition to the sample tracking system, a data management system will be implemented. The central focus of the data management system will be the development of a personal computer-based project database. The project database will combine pertinent geographical, field, and analytical data. Information that will be used to populate the database will be derived from two primary sources: field observations and analytical results. Each of these sources is discussed in the following sections.

9.3.1 Computer Hardware

The database will be constructed on personal computer work stations connected through a network server. The network will provide access to various hardware peripherals, such as laser printers, backup storage devices, image scanners, and modems. Computer hardware will be upgraded to industrial and corporate standards, as necessary, in the future.

9.3.2 Computer Software

The data will be warehoused in Environmental Quality Information System (EQuIS) 6 Enterprise system that uses an SQL Server database. Geographic information system applications will be developed in ESRI ArcGIS, with additional customization performed with Visual Basic. Tables and other database reports will be generated through Microsoft Access in conjunction with Microsoft Excel and/or Microsoft Word. These software products will be upgraded to current industrial standards, as necessary.

9.3.3 Field Observations

An important part of the information that will ultimately reside in the data management system for use during the project will include the observations that are recorded in the field.

During each sampling event, appropriate field documentation will be prepared by the field personnel who performed the sampling activities. The purpose of the documentation is to create a summary and a record of the sampling event. Items to be included are discussed in the SAP.

Field observations recorded on field logs will be reviewed by the Arcadis QAM for adherence to the SAP and for consistency. Concerns identified as a result of this review will be discussed with the field personnel, corrected if possible, and (as necessary) incorporated into the data evaluation process.

If applicable, field data forms and calculations will be processed and included in appendices to the appropriate reports (when generated). The original field logs, documents, and data reductions will be kept in the project file.

9.3.4 Analytical Results

Where the laboratories have the capability, analytical results will be reported in the electronic data deliverable (EDD) or other approved electronic table-based format. Laboratory reports (results sheets) in a pdf or electronic spreadsheet format will be received from all laboratories, within the timeframe specified in the contract agreement.

Where the laboratories have the capability, the laboratory is responsible for preparing Level 2 (or similar) data packages (as defined previously) for all samples. In general, data reports for all parameters will include the following items:

- Narrative: Summary of activities that took place during the course of sample analysis, including the following information:
  - Laboratory name and address
  - Date of sample receipt
  - Cross-reference of laboratory identification number to sample ID
  - Analytical methods used
  - Deviations from specified protocol
  - Corrective actions taken

Included with the narrative will be any sample handling documents, including field and internal COC forms, air bills, and shipping tags.

- Analytical Results: These will be reported according to the method and analysis type and may include, but are not limited to, the following information, as applicable:
  - Sample ID
  - Laboratory ID
  - Date of collection
  - Date of receipt
  - Date of extraction
  - Date of analysis
  - Dilution factor
  - Detection limits
  - Counting uncertainty and confidence levels

Sample results on the report forms will be corrected for dilutions. Unless otherwise specified, results will be reported uncorrected for blank contamination.

Analytical results will be provided by the laboratory in digital format. The data packages will be examined to confirm that the correct analyses were performed for each sample submitted and that all analyses requested on the COC form were performed. If discrepancies are noted, the Arcadis QAM will be notified and will promptly follow up with the laboratory to resolve any issues.

The individual EDDs, supplied by the laboratory in EQuIS 6 file format or other approved table-based format, will be loaded into the appropriate database. Analytical data that cannot be provided by the laboratory in electronic format will be entered manually into a spreadsheet program to facilitate the entry and processing of the data to the database. After entry into the database, the EDD data will be compared to the field information previously entered into the database to confirm that all requested analytical data have been received.

9.3.5 Data Analysis and Reporting

The database management system will have several functions to facilitate the review and analysis of the data. Routines have been developed to permit the user to scan analytical data from a given site for a given media. Several output functions are also available that can be modified, as necessary, for use in the data management system.

A valuable function of the data management system will be the generation of tables of analytical results from the project databases. The capability of the data management system to directly produce tables reduces the redundant manual entry of analytical results during report preparation and precludes transcription errors that may occur otherwise. This data management system function creates a digital file of analytical results and qualifiers for a given media. The file can then be processed into a table of rows and columns that can be transferred to a word processing software (e.g., Microsoft® Excel) for final formatting and addition of titles and notes. Tables of analytical data will be produced as part of data interpretation tasks and the reporting of data to the client. Analytical data may also be provided to the agencies, as determined by the HMC PM.

The data management system also has the capability of producing a digital file of select parameters that exists in one or more of the databases. This type of custom function is accomplished on an interactive basis and is best used for transferring select information into a number of analysis tools, such as statistical or graphing programs.

10 QUALITY CONTROL REQUIREMENTS

The QA officers at each laboratory will be responsible for conducting and reporting corrective actions if problems arise during the course of laboratory analytical procedures.

10.1 Quality Assurance Indicators

The overall QA objective for this assessment is to develop and implement procedures for sampling, COC, laboratory analysis, instrument calibration, data reduction and reporting, internal QC, preventive maintenance, and corrective action such that valid data will be generated for site assessment purposes. These procedures are presented or referenced in subsequent sections of this QAPP.

QA objectives are generally defined in terms of five parameters:

1. Representativeness
2. Comparability
3. Completeness
4. Precision
5. Accuracy
6. Sensitivity

Each parameter is defined below. Specific objectives for this assessment are set forth in other sections of this QAPP as referenced below.

10.1.1 Representativeness

Representativeness is the degree to which sample data accurately and precisely represent site conditions, and is dependent on sampling and analytical variability and the variability (or homogeneity) of the site. The site assessment has been designed to assess the presence of the chemical constituents and supplemental parameters at the time of sampling and throughout the study area. The SAP and this QAPP present field sampling methodologies and laboratory analytical methodologies. The use of the prescribed field and laboratory analytical methods with associated holding times and preservation requirements are intended to provide representative data.

10.1.2 Comparability

Comparability is the degree of confidence with which one dataset can be compared to another. Comparability between phases of the current assessment, and to the extent possible, between new and existing data will be maintained through consistent use of the sampling and analytical methodologies set forth in this QAPP and the SAP through stringent application of established QA/QC procedures and through utilization of appropriately trained personnel.

10.1.3 Completeness

Completeness is defined as a measure of the amount of valid data obtained from an event and/or investigation compared to the total amount that was obtained. This will be determined upon final assessment of the analytical results. Completeness is also a measure of how many data were collected as compared to the total amount that were planned to be collected.

10.1.4 Precision

Precision is a measure of the reproducibility of sample results. The goal is to maintain a level of analytical precision consistent with the objectives of the site assessment. To maximize precision, sampling and analytical procedures will be strictly followed; work will adhere to established protocols presented in this QAPP and SAP. Checks for analytical precision will include the analysis of MS/MSD pairs (as applicable to the method), laboratory duplicates, and field duplicates. Field measurement precision will be monitored by obtaining duplicate field measurements.

10.1.5 Accuracy

Accuracy is a measure of how close a measured result is to the true value. Recovery of reference standards, MSs, laboratory control standards, and surrogate standards, where applicable to the method, will be used to assess the accuracy of the analytical data.

10.1.6 Sensitivity

Sensitivity is defined as the ability of the method or instrument to detect the constituent of concern and other target compounds at the level of interest. The method detection limit (MDL) is defined as the minimum concentration of a substance that can be identified, measured, and reported with a 99% confidence that the analyte concentration is greater than zero and is determined from repeated analysis of a sample in a given matrix containing the analyte. MDLs have been determined as required in Title 40 of the Code of Federal Regulations Part 136B. The reporting limit (RL) is greater than or equal to the lowest standard used to establish the calibration curve. The RLs for this investigation are generally at least 3 times greater than the MDL. Results greater than the MDL and less than the RL will be qualified estimated (J) by the laboratory. For radiochemical analyses in water, the detection limit shall be that activity concentration, which can be counted with a precision of plus or minus 100% at the 95% confidence level.

10.2 Field Quality Control Checks

10.2.1 Sample Containers

Containers will be supplied by the laboratory and are pre-cleaned.

10.2.2 Field Duplicates

Field duplicates will be collected to verify the reproducibility of the sampling methods. In general, field duplicates will be analyzed at a 5% frequency (one in every 20 samples) for the chemical constituents. The SAP provides the frequency at which field duplicates will be prepared for this investigation.

10.2.3 Equipment Blanks

Equipment blanks are used to monitor the cleanliness of the sampling equipment and the effectiveness of the decontamination procedures. Equipment blanks will be prepared and submitted for analysis at a 5% frequency (one in every 20 samples) for relevant sample collection activities. Equipment blanks will not be collected for soil samples if the soil will be accessed directly using single-use, sterile, disposable scoops and placed directly into the laboratory-supplied sample container; if reusable equipment is used, an equipment blank will be collected by pouring laboratory-supplied water over the decontaminated equipment and submitting to the laboratory for analysis. Equipment blanks for water will be prepared by filling sample containers with analyte-free water (supplied by the laboratory) or purchased from a laboratory supply vendor that has been routed through a cleaned sampling device. When dedicated sampling devices are used or sample containers are used to collect the samples, equipment blanks will not be necessary.

10.2.4 Field Blanks – Clean Water Source

The clean water source blank (field blank) sample is a sample of the water source used for final equipment cleaning/rinsing and is collected and analyzed to assess the integrity of the water source. One field blank sample will be collected for each source of clean water used during the sampling event. The field blank sample will be collected from the water source in appropriate sample containers provided by the laboratory. When dedicated sampling devices or sample containers are used to collect the samples, field blank samples will not be necessary.

10.3 Analytical Laboratory Quality Control Checks

Internal laboratory QC checks will be used to monitor data integrity. These checks may include method blanks, MS/MSD pairs, LCSs, laboratory duplicates, internal standards, and calibration standards. Where applicable, laboratory control charts will be used to determine long-term instrument trends. Control limits for the QC samples will be consistent with the analytical method requirements and/or laboratory generated limits.

10.3.1 Method Blanks

Sources of contamination in the analytical process, whether specific analyses or interferences, must be identified, isolated, and corrected. The method blank is useful in identifying possible sources of contamination within the analytical process. For this reason, it is necessary that the method blank be initiated at the beginning of the analytical process (where applicable to the method) and encompasses all aspects of the analytical work. As such, the method blank would assist in accounting for any potential contamination attributable to glassware, reagents, instrumentation, or other sources that could affect sample analysis. One method blank will be analyzed with each analytical series associated with no more than 20 samples. Ideally, method blanks should not contain any detected analytes above the RL.

10.3.2 Matrix Spike/Matrix Spike Duplicates

Where applicable to the method, MS/MSDs will be used to measure the accuracy of analyte recovery from the sample matrices and will be site-specific. MS/MSD pairs will be analyzed at a 5% frequency (every 20 samples).

When MS recoveries are outside QC limits, associated LCS recoveries will be evaluated, as applicable, to attempt to verify the reason for the deviation and determine the effect on the reported sample results. The SAP provides the frequency at which MS/MSD pairs will be collected for this field investigation.

10.3.3 Laboratory Control Samples

Where applicable to the method, LCSs are standards of known concentration and are independent in origin from the calibration standards. The intent of LCS analysis is to provide insight into the analytical proficiency within an analytical series. This includes preparation of calibration standards, validity of calibration, sample preparation, instrument setup, and the premises inherent in quantitation. Reference standards will be analyzed at the frequencies specified within the analytical methods.

10.3.4 Laboratory Duplicates

Where applicable to the method, laboratory duplicates will be analyzed to assess laboratory precision. Laboratory duplicates are defined as a separate aliquot of an individual sample that is analyzed as a separate sample. For this Site, when MS/MSD pairs are not performed for certain methods, a site-specific laboratory duplicate will be requested. In this case, laboratory duplicates will be requested at a 5% frequency (every 20 samples).

10.3.5 Calibration Standards

Calibration check standards analyzed within a particular analytical series provide insight regarding instrument stability. A calibration check standard will be analyzed, where applicable to the method, at the beginning and end of an analytical series, or periodically throughout a series containing a large number of samples, per method requirements.

In general, calibration check standards will be analyzed after every 12 hours or more frequently, as specified in the applicable analytical method. If results of the calibration check standard exceed specified tolerances, samples analyzed since the last acceptable calibration check standard will be re-analyzed.

Laboratory instrument calibration standards will be selected utilizing the guidance provided in the analytical methods as summarized in Section 8.2.

10.4 Data Precision Assessment Procedures

Field precision is difficult to measure because of temporal variations in field parameters. However, precision will be controlled through the use of experienced field personnel, properly calibrated meters, and duplicate field measurements. Field duplicates will be used to assess precision for the entire measurement system, including sampling, handling, shipping, storage, preparation, and analysis.

Laboratory data precision for analyses will be monitored through the use of MSDs, laboratory duplicates, and field duplicates, where applicable to the method. The RPD for MSD and laboratory duplicate pairs will be within laboratory-generated control limits or as specified by the analytical method. For field duplicate analyses, RPD criteria are ≤50% for soil samples and ≤35% for water samples.

The precision of data will be measured by calculation of the RPD by the following equation:

$$RPD = \frac{(A-B)}{\frac{(A+B)}{2}} * 100$$

Where:

A = Analytical result from one of two duplicate measurements

B = Analytical result from the second measurement

10.5 Data Accuracy Assessment Procedures

The accuracy of field measurements will be controlled by experienced field personnel, properly calibrated field meters, and adherence to established protocols. The accuracy of field meters will be assessed by review of calibration and maintenance logs.

Where applicable to the method, laboratory accuracy will be assessed using MSs, LCS, internal standards, and reference standards. Where available and appropriate, QA performance standards will be analyzed periodically to assess laboratory accuracy. Recoveries will be assessed against laboratory established limits or as specified in the analytical method. Accuracy will be calculated in terms of percent recovery as follows:

$$\%Recovery = \frac{(A-X)}{B} * 100$$

Where:

A = Value measured in spiked sample or standard

X = Value measured in original sample

B = True value of amount added to sample or true value of standard

11 ASSESSMENT AND RESPONSE ACTIONS

If necessary, performance and systems assessments will be completed in the field and the laboratory, as described below.

11.1 Field Performance

The following field performance reviews may be completed during this project.

The Arcadis Technical Lead will monitor field performance. Field performance summaries will contain an evaluation of field activities to verify that the activities are performed according to established protocols. Field performance reviews may be performed by the Arcadis QAM. The reviewer(s) will review field reports and communicate concerns to the Arcadis PM and/or Technical Lead and/or HMC, as appropriate.

Observations made during field performance reviews and any recommended changes/deviations to the field procedures will be recorded and documented. The observations and any recommendations will be distributed to the HMC Project Team, as appropriate.

In addition, actual QA/QC activities completed will be compared against reviews of QA/QC activities described in this QAPP. The Arcadis QAM will periodically confirm that work is being performed consistently with this QAPP.

11.2 Corrective Action

Corrective actions are required when field or analytical data are not within the objectives specified in this QAPP or the SAP. Corrective actions include procedures to promptly investigate, document, evaluate, and correct data collection and/or analytical procedures. Field and laboratory corrective action procedures for the assessment are described below.

11.2.1 Field Procedures

If, during field work, a condition is noted by the field crew that would have an adverse effect on data quality, corrective action will be taken so as not to repeat this condition. Condition identification, cause, and corrective action implemented by the field personnel will be documented and reported to the Arcadis Technical Lead and QAM. The Arcadis QAM or designee will be responsible for follow-up and acceptance of corrective actions.

Examples of situations that would require corrective actions are provided below:

- Protocols as defined by the QAPP or SAP have not been followed
- Equipment is not in proper working order or properly calibrated
- QC requirements have not been met

Project personnel will continuously monitor ongoing work performance in the normal course of daily responsibilities.

11.2.2 Laboratory Procedures

In the laboratory, when a condition is noted to have an adverse effect on data quality, corrective action will be taken so as not to repeat this condition. Condition identification, cause, and corrective action to be taken will be documented, and reported to the appropriate laboratory PM and QAM. If previously reported data are affected by a situation requiring correction or if the corrective action impacts a project budget or schedule, the laboratory PM and QAM will contact the Arcadis PM, Technical Lead, or QAM.

12 DATA REDUCTION AND REVIEW

12.1 General

After field and laboratory data are obtained, the data will be subjected to the following:

- Reduction, or manipulation mathematically or otherwise into meaningful and useful forms
- Data verification check between sample results contained in the pdf of the laboratory report and EDDs (where provided) will be performed at a rate of 10% by the Arcadis QAM or designee
- Tier I data validation on Level 2 reports
- Organization, interpretation, and reporting

12.2 Field Data Reduction and Review

12.2.1 Field Data Reduction

Information collected in the field through visual observation, manual measurement, and/or field instrumentation will be recorded in field log books, data sheets, and/or on forms as described above and in the SAP. Such data will be reviewed by the Arcadis QAM or designee for adherence to the SAP and this QAPP and for consistency. Concerns identified as a result of this review will be discussed with field personnel, corrected if possible, and (as necessary) incorporated into the data evaluation process.

12.2.2 Field Data Review

Field data calculations, transfers, and interpretations will be conducted by the field personnel and reviewed for accuracy by the Arcadis QAM or designee. Logs and documents will be checked for:

- General completeness
- Readability
- Usage of appropriate procedures
- Appropriate instrument calibration and maintenance
- Reasonableness in comparison to present and past data collected
- Correct sample locations
- Correct calculations and interpretations

12.3 Laboratory Data Reduction and Review

12.3.1 Laboratory Data Reduction

The calculations used for data reduction will be in accordance with the analytical methods. Whenever possible, analytical data will be transferred directly from the instrument to a computerized data system. Raw data will be entered into permanently bound laboratory notebooks. The data entered must be sufficient to document all factors used to arrive at the reported value.

13 DATA VALIDATION

Data validation will be conducted, as outlined in USEPA Guidance on Environmental Data Verification and Data Validation EPA QA/G-8 (USEPA 2002).

Data validation is a standardized review process for judging the analytical quality and usefulness of a discrete set of chemical data and is necessary to ensure that data of known and documented quality are used in making environmental decisions that meet the DQOs of the Site. Data validation is a systematic process that compares a body of data to the requirements in a set of documented acceptance criteria to ascertain its completeness, correctness, and consistency.

13.1 Data Validation Process

All data generated will be validated using USEPA National Functional Guidelines for Inorganic Superfund Methods Data Review, EPA 540-R-2017-001, January 2017 (with reference to the historical USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, OSWER 9240.1-45, October 2004, as appropriate) upon receipt of all of the laboratory-generated data, where appropriate. These procedures and criteria may be modified, as necessary, to address project-specific and method-specific criteria, control limits, and procedures. Data validation will consist of data screening, checking, and reviewing to document analytical data quality and to determine whether the quality is sufficient to meet the DQOs.

Upon receipt of all laboratory data, the following validation procedures will be executed as a Tier I level validation:

- Evaluate completeness of data package.
- Verify that field COC forms were completed and that samples were handled properly.
- Verify that holding times were met for each parameter. Holding time exceedances, if they occur, will be documented. Data for all samples exceeding holding time requirements will be flagged as either estimated or rejected. The decision as to which qualifier is more appropriate will be made on a case-by-case basis.
- Verify that parameters were analyzed according to the methods specified.
- Review QA/QC data [i.e., confirm that laboratory QC checks (LCS, MS/MSD, laboratory duplicates) were analyzed for the required number of samples as specified in the method and that the recoveries and RPDs were within the laboratory-generated or method-specified control limit].
- Review blank results (i.e., method blanks, instrument calibration blanks, field blanks, and equipment blanks) and evaluate potential impacts to field sample results.
- Investigate all anomalies identified during review. When anomalies are identified, they will be discussed with the Arcadis PM and Technical Lead and/or laboratory PM, as appropriate.

Deficiencies discovered as a result of the data review, as well as the corrective actions implemented in response, will be documented and submitted in the form of a written report addressing the following topics, as applicable to each method:

- Assessment of the data package
- Description of any protocol deviations
- Assessment of any compromised data
- Overall appraisal of the analytical data
- Table of site name, sample quantities, matrix, and fractions analyzed

It should be noted that qualified results do not necessarily invalidate data. The goal to produce the best possible data does not necessarily mean that data must be produced without QC qualifiers. Qualified data can provide useful information.

During the review process, laboratory qualified and unqualified data are verified against the supporting documentation. Based on this evaluation, qualifier codes may be added, deleted, or modified by the data reviewer. Results will be qualified in accordance with National Functional Guidelines (USEPA 2017).

Resolution of issues regarding laboratory performance or deliverables will be handled between the laboratory and the data validator. Suggestions for re-analysis may be made by the laboratory PM or QAM at this point.

Data validation reports will be kept in electronic format (pdf) at the environmental consultant’s office.

14 RECONCILIATION WITH USER REQUIREMENTS

Data results will be examined to determine the performance that was achieved for each data usability criterion. The performance will then be compared with the project objectives and DQOs. Deviations from objectives will be noted. Additional action may be warranted when performance does not meet performance objectives for critical data. Options for corrective action relating to incomplete information, questionable results, or inconsistent data may include any or all of the following:

- Retrieval of missing information
- Request for additional explanation or clarification
- Reanalysis of sample from extract (when appropriate)
- Re-calculation or reinterpretation of results by the laboratory

These actions may improve the data quality, reduce uncertainty, and eliminate the need to qualify or reject data.

If these actions do not improve the data quality to an acceptable level, the following additional actions may be taken:

- Extrapolation of missing data from existing data points
- Use of historical data
- Evaluation of the critical/non-critical nature of the sample

If the data gap cannot be resolved by these actions, an evaluation of the data bias and potential for false negatives and positives can be performed. If the resultant uncertainty level is unacceptable, additional sample collection and analysis may be required.

15 REFERENCES

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SAP
APPENDIX B
Field Forms

Geophysical Logging Field Form

ARCADIS Design & Consultancy for natural and built assets

All Personnel Present: ____________________

Date/Time: ____________________

Site: ____________________ **Weather Conditions:** ____________

Location: ____________________

Well ID: ____________________

Well Type: ☐Monitoring ☐Other: ____________________

Well Finish: ☐Stick Up ☐Flush Mount

Measuring Pt: ☐Top of Casing ☐Other (specify):____________________

Total Depth (ft bgs): ____________________ **Screened Interval (ft bgs):**____________

Well Casing: Diameter (in.):_______________ Material: ____________________

Well Screen: Diameter (in.):_______________

Static depth to water: ____________________ ft btoc

Geophysical Tool	Make/Model	Calibrated?	Time in	Time out	Logging Speed	Depth Deployed (ft bTOC)

Casing condition:

Notes/Observations: *(e.g. reproducibility of data acquisition, preliminary results, decontamination procedures, picture #s)*

SAP
APPENDIX C
Standard Operating Procedures

ARCADIS
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Field Log Book Entries

Rev. #: 0

Rev Date: 11 August 2009

I. Scope and Application

This ARCADIS Standard Operating Procedure covers the entries needed in a field log book for environmental investigations.

This SOP does not address all of the entries that may be needed for a specific project, and does not address health and safety, equipment decontamination, field parameter measurements, sample preservation, chain-of-custody, or laboratory analysis. For direction on requirements in these areas, refer to other ARCADIS SOPs, the project work plans including the quality assurance project plan, sampling plan, and health and safety plan, as appropriate.

II. Personnel Qualifications

ARCADIS personnel participating in fieldwork and making entries into the field log book should have a minimum of one (1) year of field experience (or be under the supervision and accompanied in the field by someone who does) and current health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and CPR, as needed. Field personnel will also be compliant with client-specific training requirements. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and posses the required skills and experience necessary to successfully complete the desired field work.

III. Equipment List

- Field Log Book
- Ball point (medium point) pen with blue or black ink (black preferred). A fine point Sharpie pen may be used if the ink does not bleed through the page and become visible on back side of the page. If weather conditions prevent the use of a pen, indicate so in the log and use an alternate writing instrument .
- Zip-lock baggie or other weather-proof container to protect the field log book from the elements.

IV. Cautions

All entries in the field log must be legible and archivable. Do not leave the field log book exposed to the elements or other conditions that might moisten the pages and smear/dissolve the entries. When not in the field, the log book should be stored in a location that is easily accessible to field crews.

V. Health and Safety Considerations

ARCADIS field personnel will be familiar and compliant with Client-specific health and safety requirements.

VI. Procedure

- Print legibly. Do not use cursive writing.
- The name of the project, project number and project location should be written in indelible ink on the outside of the field log book.
- On the inside of the front cover, write “If Found, Please Return to ARCADIS” and include the appropriate address and phone number, the name of the person to which the book is assigned, and the name of the project manager.
- Reserve the first page of the book for a Table of Contents.
- Reserve the last five (5) pages of the book for important contacts, notes, reminders, etc.
- Each day of field work, the following should be recorded in the field log book as applicable:

  a) Project Name

  b) Date and time arrived

  c) Work Site Location

  d) Names of people on-site related to the project including ARCADIS employees, visitors, subcontractor employees, agency personnel, client representative, etc.

  e) Describe the work to be performed briefly, and list the equipment on-site

  f) Indicate the health and safety (H&S) level to be used

  g) Record instrument calibrations and checks

  h) Record time and general content of H&S briefing

  i) Describe the weather conditions, including temperature, precipitation, and wind speed and direction

  j) List periodic time entries in the far left hand column of each page

  k) Minimize unused space on each page
- The tailgate meeting must be recorded in the log book and the tailgate form completed. If H&S monitoring is performed, record the time and results of initial and followup monitoring.

- Note factual observations including collection of QA/QC samples, delays, well damage, accidents, work plan deviations, instrument problems, and problem resolutions.

- Describe work performed and how documented such as photographs, sample core logs, water sampling logs, etc.

- Describe bases for field decisions including pertinent conversations with visitors, regulators, or project personnel.

- Note final instrument calibrations and checks.

- Sign the log book at the end of each day at a minimum. Draw a line to the end of the page to indicate no further entries on that page. Sign the bottom of each page if possible.

- If an entry to the log book is changed, strike out the deleted text or item with a single line such that the entry remains legible, and initial and date the change. Such changes should only be made by the same person that made the initial entry.

- Field log book entries must be made in the field at the site, not at a later time at a different location. Supplemental entries to the log book may be made at a later date. The supplemental entry must be clearly identified as such and the entry must be signed and dated as described in this SOP.

- Problems noted in the field log book must be brought to the attention of the project manager and task manager in a timely fashion. Problems may be reported in person, on the telephone, or in a written daily log form. If daily logs are prepared and you will not be able to personally give the daily log to the project manager, send the daily log via FAX or overnight courier to the project manager and task manager.

VII. Waste Management

Investigation-derived waste will be managed as described in the Investigation-Derived Waste Handling and Storage SOP. A drum/waste inventory should be maintained on a pre-designated page in the field log book.

VIII. Data Recording and Management

Each page of the field log book should be scanned for electronic/digital archiving at periodic intervals. This will ensure that copies of the field notes are available in the event the field book is lost or damaged, and that field data can be easily disseminated to others without the risk of physically sending the field log book. Field log books that are full should be archived with the project files, and readily retrievable.

IX. Quality Assurance

Be mindful that the field log book may be produced in court. All entries should be legible (as discussed above). Entries should also be in English, unless working in a country where English is not the predominant language or you are directed otherwise by the project manager.

X. References

Not Applicable

ARCADIS
Infrastructure, environment, facilities

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Water Level Measurement

Rev. #: 2

Rev Date: February 24, 2011

I. Scope and Application

The objective of this Standard Operating Procedure (SOP) is to describe procedures to measure and record groundwater and surface-water elevations. Water levels may be measured using an electronic water-level probe, oil-water level indicator, or a pressure transducer from established reference points (e.g. top of casing). Reference points will be surveyed to evaluate fluid elevations relative to mean sea level (msl). This SOP describes the equipment, field procedures, materials, and documentation procedures to measure and record groundwater and surface-water elevations using the aforementioned equipment.

This is a standard (i.e., typically applicable) operating procedure which may be varied or changed as required, dependent upon site conditions, equipment limitations, or limitations imposed by the procedure. The ultimate procedure employed will be documented in the project work plans or reports.

II. Personnel Qualifications

ARCADIS field sampling personnel will have current health and safety training including 40-hour HAZWOPER training, site supervisor training, site-specific training, first aid, and CPR, as needed. In addition, ARCADIS field sampling personnel will be versed in the relevant SOPs and posses the required skills and experience necessary to successfully complete the desired field work.

III. Equipment List

The following materials, as required, shall be available during water level measurements:

- Appropriate personal protective equipment as specified in the Site Health and Safety Plan
- Equipment decontamination supplies
- Electronic water-level indicator
- Electronic oil-water level indicator
- Mini-Troll® or Troll® pressure transducer
- In-Situ™ data logger

- Laptop computer with the Win-Situ software package installed
- Photoionization detector (PID) and/or organic vapor analyzer
- Non-phosphate laboratory soap (Alconox or equivalent)
- Deionized/distilled water
- 150-foot measuring tape
- Solvent (methanol/acetone) rinse
- Portable containers
- Hacksaw
- Pliers
- Plastic sheeting
- “Write-in-the-Rain” Field logbook and or PDA (Personal Digital Assistant)
- Indelible ink pen.

IV. Cautions

Electronic water-level probes and oil-water interface probes can sometimes produce false-positive readings. For example, if the inside surface of the well has condensation above the water level, then an electronic water-level probe may produce a signal by contacting the side of the well rather than the true water level in the well. To produce reliable data, the electronic water level probe and/or interface probe should be raised and lowered several times at the approximate depth where the instrument produces a tone indicating a fluid interface to verify consistent, repeatable results.

The graduated tape or cable with depth markings is designed to indicate the depth of the electronic sensor that detects the fluid interface, but not the depth of the bottom of the instrument. When using these devices to measure the total well depth, the additional length of the instrument below the electronic sensor must be added to the apparent well depth reading, as observed on the tape or cable of the instrument, to obtain the true total depth of the well. If the depth markings on the tape or cable are worn or otherwise difficult to read, extra care must be taken in obtaining the depth readings.

V. Health and Safety Considerations

The HASP will be followed, as appropriate, to ensure the safety of field personnel. Access to wells may expose field personnel to hazardous materials such as contaminated groundwater or oil. Other potential hazards include stinging insects that may inhabit well heads, other biologic hazards, and potentially the use of sharp cutting tools (scissors, knife). Appropriate personal protective equipment (PPE) will be worn during these activities. Field personnel will thoroughly review client-specific health and safety requirements, which may preclude the use of fixed/folding-blade knives.

VI. Procedure

Electronic Water-Level Indicators and Oil-Water Indicators

Calibration procedures and groundwater level measurement procedures for electronic water-level indicators and oil-water indicators are described in the sections below.

Calibration Procedures

The indicator probe will be tested to verify that the meter has been correctly calibrated by the manufacturer. The following steps will be used to verify the accuracy of the indicator:

1. Measure the lengths between each increment marker on the indicator with a measuring tape. The appropriate length of indicator measuring tape, suitable to cover the depth range for the wells of interest, will be checked for accuracy.

2. If the indicator measuring tape is inaccurate, the probe will be sent back to the manufacturer.

3. Equipment calibration will be recorded in the field logbook and/or PDA.

Groundwater Level Measurement Procedures

A detailed procedure for obtaining water elevations will be as follows:

1. Identify site and monitoring well number in field notebook along with date, time, personnel and weather conditions using indelible ink.

2. Use safety equipment as specified in the Health and Safety Plan.

3. Decontaminate the indicator probe and tape in accordance with the appropriate cleaning procedures.

4. Place clean plastic sheeting on the ground next to the well.

5. Unlock and open the monitoring well cover while standing upwind from the well.

6. Measure the volatile organics present in the monitoring well head space with a PID and record the PID reading in the field logbook.

7. Allow the water level in the well to equilibrate with atmospheric pressure for a few minutes. Locate a measuring reference point on the monitoring well casing. If one is not found, create a reference point by notching the highest point on the inner casing (or outer if an inner casing is not present) with a hacksaw. All downhole measurements will be taken from the reference point. Document the creation of any new reference point or alteration of the existing reference point.

8. Measure to the nearest 0.01 foot and record the height of the inner and outer casing from reference point to ground level.

9. Slowly lower the level indicator probe until it touches the bottom of the well. Record the total depth of the well from the top of the inner casing (or outer casing if inner casing is not present). Measure depth to water level as the probe is drawn back up through the water column. If used to measure the level of surface water, slowly lower from the surveyed reference point, as appropriate. Double check all measurements and record depths to the nearest 0.01 foot.

10. Decontaminate the instrument using appropriate cleaning procedures.

11. Lock the well when all activities are completed.

Pressure Transducers

The detailed procedure for obtaining water elevations using a Mini-Troll® or Troll® pressure transducer with an In-Situ™ data logger and the Win-Situ software package will be as follows:

Setup Procedures

1. Connect the Mini-Troll® or Troll® transducer to a laptop computer serial port.

2. Open the Win-Situ software package on the laptop computer.

3. Verify that the Win-Situ software recognizes the transducer.

4. Synchronize the clock on the laptop computer with that of the transducer.

5. Add a test to the transducer and input the specifications of the test (e.g., frequency of data collection, start data collection).

6. Disconnect the transducer from the laptop computer, and prepare the transducer for field deployment.

Field Procedures

1. Decontaminate all equipment entering the monitoring well using appropriate cleaning procedures.

2. Connect transducer to laptop computer, and start the Win-Situ program.

3. Lower the transducer gently below the water table or surface-water level.

4. Take a water level reading from the transducer using the Win-Situ software package. Lift the transducer approximately 1-foot, and verify the transducer response on the Win-Situ program (i.e. depth to water should be 1-foot less).

5. Upon verification, set the transducer to the desired depth. Position the instrument below the lowest anticipated water level, but not so low that its range will be exceeded at the highest anticipated water level. The maximum operating depth below water is equal to 2.31 feet times the psi rating of the transducer (e.g., 23.1 feet for a 10 psi transducer).

6. Secure the cable at the well head or fixed object adjacent to surface-water body to prevent drift and movement.

7. Obtain a manual water-level reading using the procedure noted above, and record the measurement in the field notebook or PDA.

8. Set reference point (e.g. depth to water, groundwater elevation) and input it into the Win-Situ software package.

9. Periodically download data and collect additional manual depth-to-water measurements using the same water-level or oil-water indicator probe used during the equipment setup to verify the accuracy of the transducer.

VII. Waste Management

Decontamination fluids, PPE, and other disposable equipment will be properly stored on site in labeled containers and disposed of properly. Be certain that waste containers are properly labeled and documented in the field log book. Review appropriate waste management SOPs, which may be state- or client-specific.

VIII. Data Recording and Management

Groundwater level measurements should be documented in the field logbook and/or PDA. The following information will be documented in the field logbook:

- Sample identification
- Measurement time
- Total well depth
- Depth to water

Groundwater elevations recorded using a Mini-Troll® or Troll® pressure transducer with an In-Situ™ data logger and the Win-Situ software package will be downloaded and stored in the central project file.

IX. Quality Assurance

As described in the detailed procedure, the electronic water-level meter and/or oil-water interface probe will be calibrated prior to use versus an engineer’s rule to ensure accurate length demarcations on the tape or cable. Fluid interface measurements will be verified by gently raising and lowering the instrument through each interface to confirm repeatable results.

X. References

No literature references are required for this SOP.

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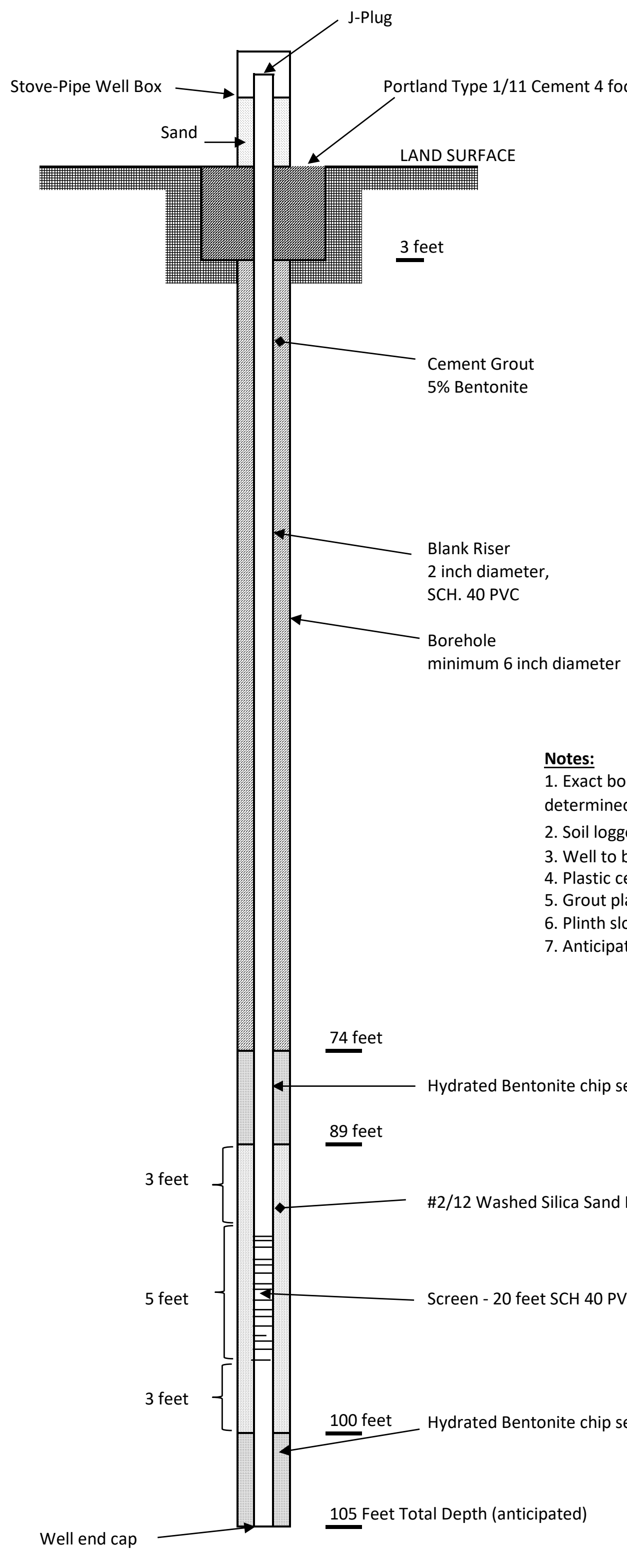
WORK PLAN
APPENDIX B

Proposed Well Construction Diagrams

Figure B-1
Proposed Course Sediment Well Construction Diagram
2019 Background Investigation
Grants Reclamation Project



Project Grants Reclamation Project Wells GF1-CS and GF2-CS

Town/City Grants

County ______ State New Mexico

Permit No. TBD

Land-Surface Elevation and Datum:

______ feet ☐ Surveyed

☐ Estimated

Installation Date(s) TBD

Drilling Method Sonic

Drilling Contractor TBD

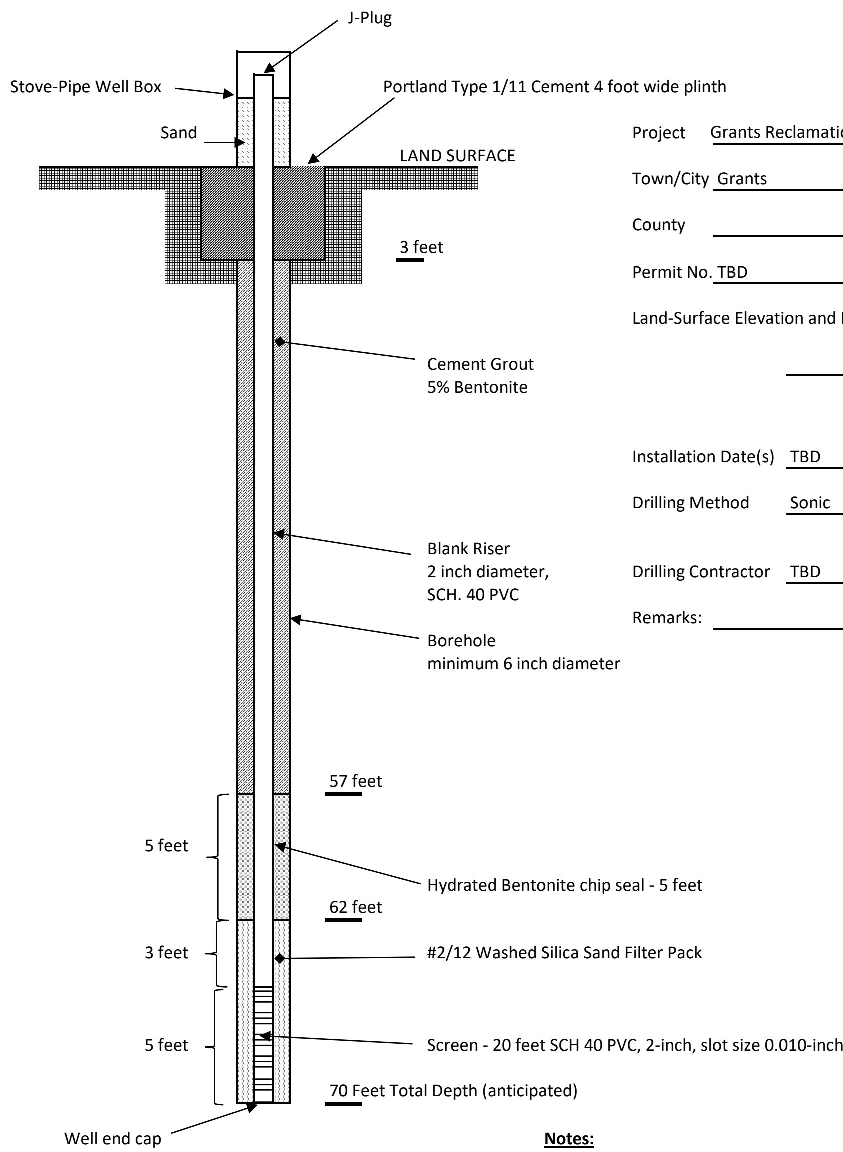
Remarks: ______

Notes:

1. Exact bore completion depth, screen length and placement to be determined based on lithology at each well location
2. Soil logged in accordance with ASTM designation D2488
3. Well to be surveyed by licensed surveyor
4. Plastic centralizers to be placed at bottom and top of screen
5. Grout placed with tremie pipe and positive displacement
6. Plinth sloped to drain water away from well
7. Anticipated depth to water 45 feet below ground surface

DRAWING IS NOT TO SCALE

Figure B-2
Proposed Fine Sediment Well Construction Diagram
2019 Background Investigation
Grants Reclamation Project



Project Grants Reclamation Project Wells GF1-FS and GF2-FS

Town/City Grants

County ______ State New Mexico

Permit No. TBD

Land-Surface Elevation and Datum:

______ feet ☐ Surveyed

☐ Estimated

Installation Date(s) TBD

Drilling Method Sonic

Drilling Contractor TBD

Remarks: ______

DRAWING IS NOT TO SCALE

Notes:

1. Exact bore completion depth, screen length and placement to be determined based on lithology at each well location
2. Soil logged in accordance with ASTM designation D2488
3. Well to be surveyed by licensed surveyor
4. Plastic centralizers to be placed at bottom and top of screen
5. Grout placed with tremie pipe and positive displacement
6. Plinth sloped to drain water away from well
7. Anticipated depth to water 45 feet below ground surface

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